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METAL PROGRESS

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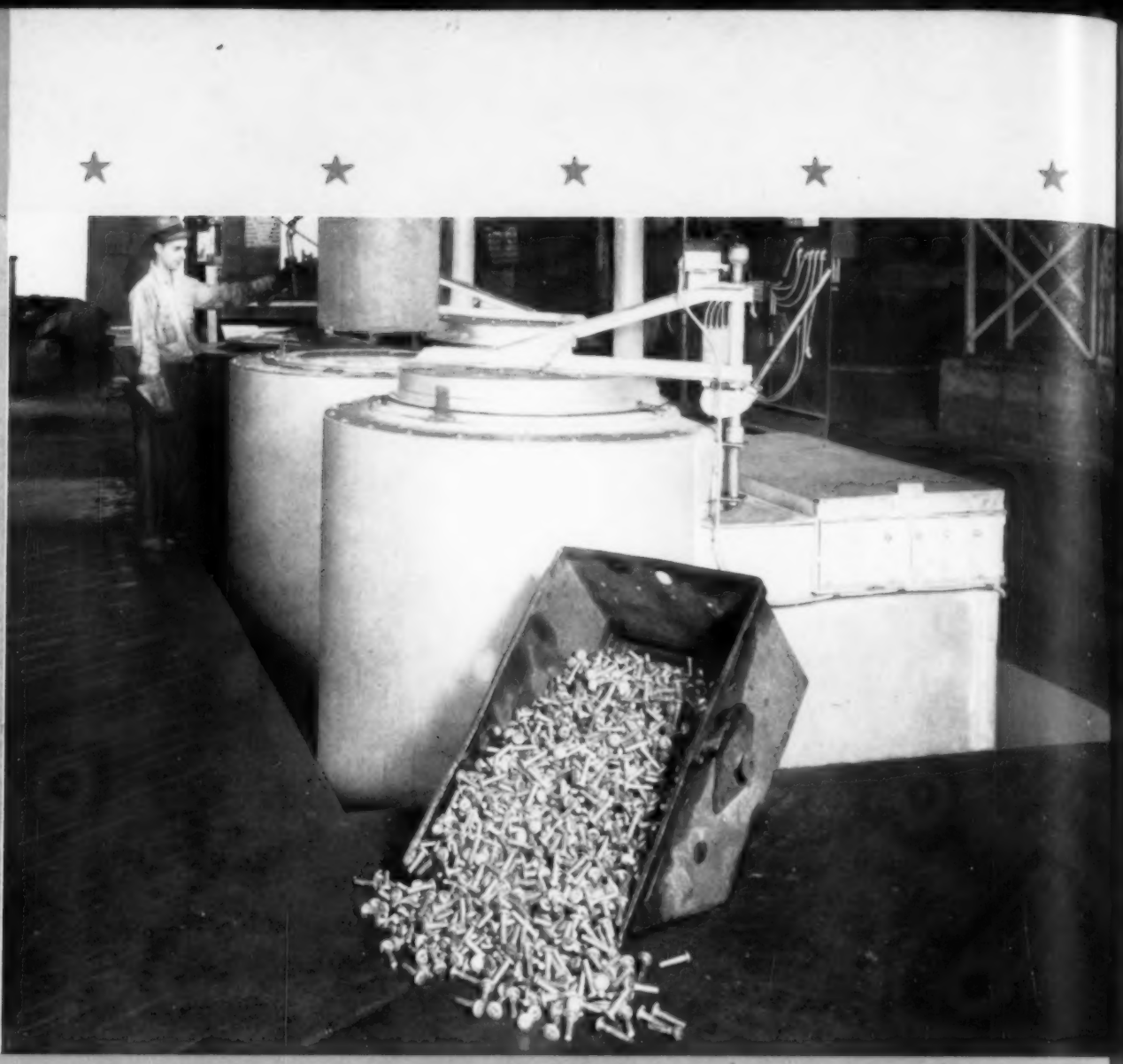

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METAL PROGRESS

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TUBES FOR OIL HEATERS

titanium or columbium in 5% Cr-Mo-Si steel

By Herbert Habart
Ellwood City Works
National Tube Co.

IN THE USE OF ALLOY STEELS for tubing in oil heaters, the trend is toward a grade possessing high creep strength, resistance to oxidation, corrosion and impact, and freedom from air hardening or susceptibility to grain growth; these must be combined with high ductility and good tensile strength. In addition to these properties, more rigid inspection demands close size tolerances and a smooth surface finish.

To meet these combined requirements, the composition of alloy steels, the melting practice and the procedure in various stages of fabrication must be coordinated. From the viewpoint of composition, the alloys should contain molybdenum to increase creep resistance and prevent brittleness, chromium and silicon to provide corrosion and oxidation resistance, and either titanium, columbium or aluminum to restrict or prevent air hardening. The cost of the alloy additions must be small, and their proportions must be selected to provide the desired physical properties and surface quality without occasioning any unusual handicaps to the melting and fabricating operations.

Both experimental and service tests have demonstrated that 5% Cr, 1% Si and 0.5% Mo form a practical composition except that it has a considerable capacity for air hardening. The addition of titanium, columbium or aluminum successfully restricts air hardening but presents another problem. Insufficient amounts of these so-called stabilizing elements are obviously of little value. Excessive amounts (particularly of titanium or columbium) promote grain growth, thereby producing brittleness and lessening ductility. Surface quality may also be impaired. On the other hand with correct proportions of the alloy elements, it is possible to obtain the desired physical properties combined with good surface quality; likewise correct amounts of titanium or columbium improve the creep strength of the steel, its impact properties and its oxidation resistance.

A study of a large number of experimental and commercial heats has shown that, with a given type of melting practice, a titanium range of 0.30 to 0.50% in heats containing 0.05 to 0.10% carbon (5% Cr, 1% Si and 0.5% Mo), is adequate for a desirable restriction of the air hardening capacity. With the same melting practice, titanium contents over 0.55% frequently eliminate all air hardening capacity, while less than 0.25% does not sufficiently restrict it. In a similar manner, a columbium range has been established at 0.50 to 0.80%.

As a result of this study, two commercial heats were prepared, both of which were of the 5% Cr, 1% Si, 0.5% Mo type. One heat *T* contained 0.39% titanium and the other heat *C* contained 0.50% columbium. The actual com-

Chemical Analyses of the Steels Studied

Symbol	Type	C	Mn	P	S	Si	Ni	Cr	Mo	Ti	Cb	Al
T	Titanium addition	0.07	0.48	0.013	0.006	1.01	0.03	4.90	0.51	0.39	..	..
C	Columbium addition	0.07	0.48	0.008	0.013	1.02	0.09	5.54	0.54	..	0.50	..
L	Low carbon	0.15	0.45	<0.04	<0.05 (nominal analysis of type)							
M	Chromium-molybdenum	0.10			(nominal analysis of type)			5.0	0.50			
S	High silicon	0.12	0.28	0.013	0.010	1.42	..	5.20	0.50	..	..	..
A	Silicon-aluminum	0.19	0.26	0.013	0.017	1.26	..	5.03	0.51	..	..	0.84
Y	Silicon-titanium	0.15	0.74	..	..	1.49	..	5.50	0.55	1.65	..	..
Z	Silicon-titanium	0.16	0.79	..	..	1.22	..	5.70	0.44	0.90	..	..
18-8	Stainless	<0.07	<0.50	<0.03	<0.03	<0.75	8.0	18.0 (nominal analysis of type)				

positions are in the first two lines of the table above.

These two alloys were investigated for their oxidation resistance, restriction of air hardening, resistance to grain growth, tensile and impact values. Surface quality was determined by inspecting seamless tubes of various sizes made from the commercial heats. Ductility and internal quality were rated from manipulating tests on finished tubes.

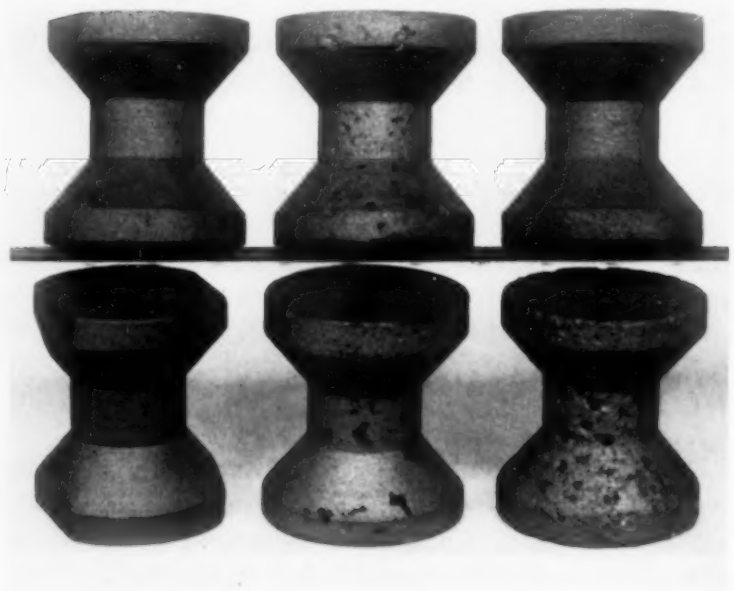
Oxidation resistance was measured by exposing samples for 168-hr. periods at each 100° F. interval between 1000° and 1600° F., and for 1000-hr. periods at 1600, 1650 and 1700° F. The apparatus was arranged to provide a mild air current during exposures.

The table on top of the next page gives the results of these tests, expressed as loss in grams per square inch of surface. Also listed for comparison are results on low carbon steel; a 5% chromium steel with 0.5% molybdenum; a similar steel with silicon up to 1.42%; and an 18% chromium, 8% nickel steel. The table also contains oxidation tests for 1000 hr. at 1600, 1650 and 1700° F. on 5% Cr, 0.5% Mo steels with various silicon, titanium and aluminum additions. Acknowledgments are made with thanks to George F. Comstock for making these long-time tests.

The cut below shows these test specimens exposed for 1000 hr. at 1600° F. after the scale has been removed by sand blasting. The three titanium alloys, symbols *T*, *Y*, and *Z*, were immune to pitting. The columbium-bearing alloy, symbol *C*, and the 1.42% silicon alloy, symbol *S*, were slightly pitted. The silicon-aluminum alloy *A* was deeply pitted. The combined data show the titanium-bearing and columbium-bearing alloys with 1% silicon to be equally as resistant to oxidation at 1600° F. as the 1.42% silicon alloy. Their superiority over the chromium-molybdenum steel *M* without additions and the low carbon steel *L* is obvious.

The effectiveness of the titanium and columbium additions in restricting the air-hardening is shown by data in the table below. Hardness values were

Steel Z C T



Steel Y S A

Test Specimens After Heating 1000 Hr. in Air at 1600° F. Scale removed by sand blasting. Titanium-bearing alloys Z, T, and Y are apparently immune to oxidation pitting. (See table above for compositions)

Hardness After Air Cooling

	Steel T	Steel C	Steel M
Annealed	149	146	137
Air cooled from			
1300° F.	146	146	137
1400	149	146	134
1500	149	146	311
1600	146	146	363
1700	149	156	363
1800	143	217	375

Tests for Oxidation Resistance

Loss in grams per square inch of surface in times specified

Symbol	Loss After 168 Hr. at							*Loss After 1000 Hr. at		
	1000° F.	1100° F.	1200° F.	1300° F.	1400° F.	1500° F.	1600° F.	1600° F.	1650° F.	1700° F.
T	0.000	0.000	0.000	0.014	0.019	0.025	0.032	0.13	5.57	10.03
C	0.000	0.000	0.000	0.015	0.016	0.019	0.030	0.34	6.44	9.05
L	0.024	0.061	0.256	0.772	1.517	2.377	3.322			
M	0.008	0.010	0.015	0.057	0.276	0.535	1.151			
S	0.000	0.000	0.000	0.011	0.018	0.022	0.034	0.20	0.28	10.15
18-8	0.000	0.000	0.000	0.000	0.000	0.005	0.009			
A								0.47	0.54	5.72
Y								0.09	0.11	0.16
Z								0.11	6.89	8.82

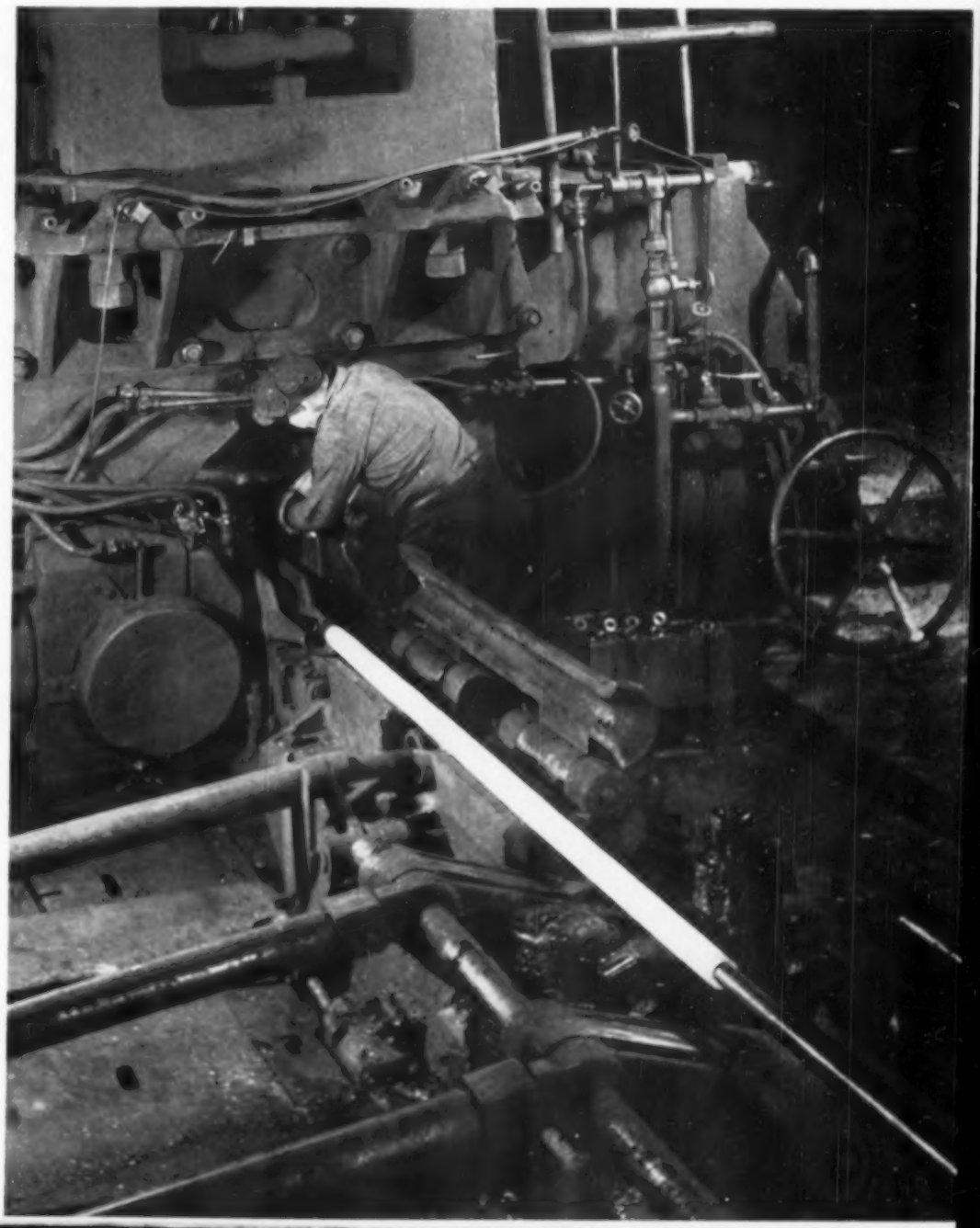
*Tests kindly made by G. F. Comstock, Titanium Alloy Mfg. Co.

obtained on samples initially annealed to approximately 145 Brinell hardness, and then reheated at each 100° interval between 1300° and 1800° F., followed by air cooling. Comparison values for the 5% Cr, 0.5% Mo steel *M* are also shown. The titanium alloy *T* did not harden throughout the range. The columbium alloy *C* slightly hardened at 1800° F. and steel *M* hardened strongly at 1500° F. or above.

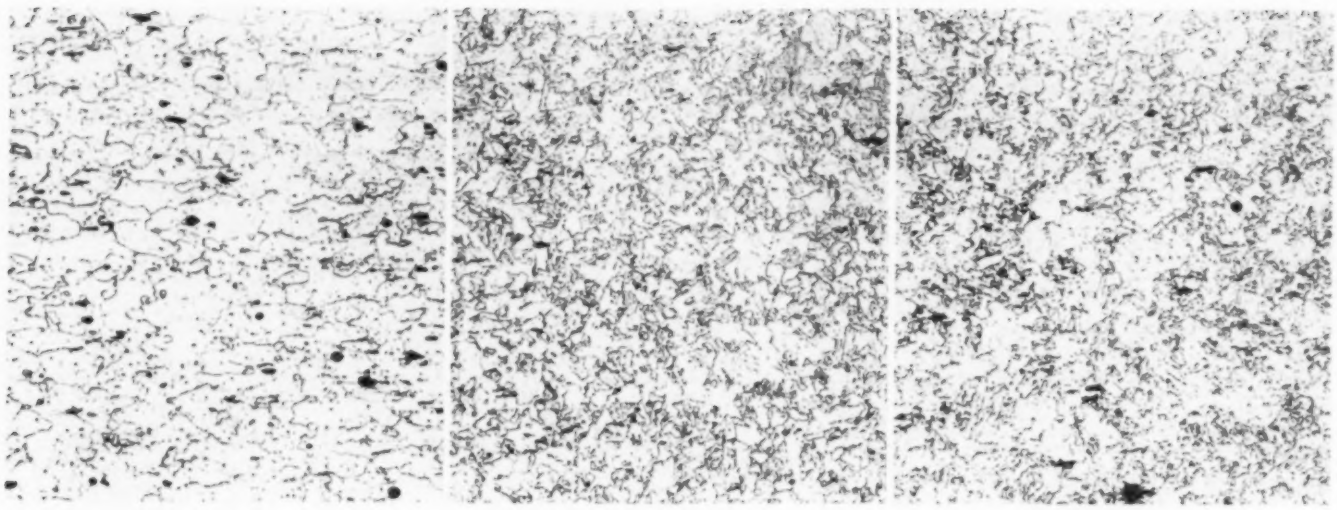
The resistance of the two alloys *T* and *C* to grain growth was tested in two ways. For the first method, 1-in. round bars of each were hot forged. Small samples from these bars were heated and held 1 hr. at temperatures between 1900° and 2400° F., followed by extremely rapid quenching in iced brine. This procedure served as a means of preserving, for subsequent metallographic examinations, the structural conditions which existed at the elevated temperatures. Grain size ratings on the resulting samples are listed in another table, in terms of grain sizes in the American Society for Testing Materials' standard.

For the second method of testing for grain growth, sections from annealed tubes were heated at 1600° F. for 2 hr., others at 1800° F. for 2 hr., and at 2000° F. for 1 hr., each followed by air cooling.

Two of the four separate lots of seamless tubes made from the titanium alloy and one of the two lots made from the columbium alloy were tested in this manner. (The tube sizes used from the titanium alloy were ½-in. outside diameter by $\frac{1}{16}$-in. wall and 3-in. outside diameter by ¼-in. wall; from the columbium alloy was 1⅝-in. outside diameter by ¼-in. wall.)



Workman Replacing Pointed Mandrel or Plug at Outlet End of Piercing Mill. Courtesy National Tube Co.



Treatment 1, Annealed 1425 | 2 Hr. at 1800° F. | 1 Hr. at 2000° F.

Grain Size of Columbium-Bearing Alloy C in 1.62 x 0.25-In. Tube; Nital Etch; 100 Diameters

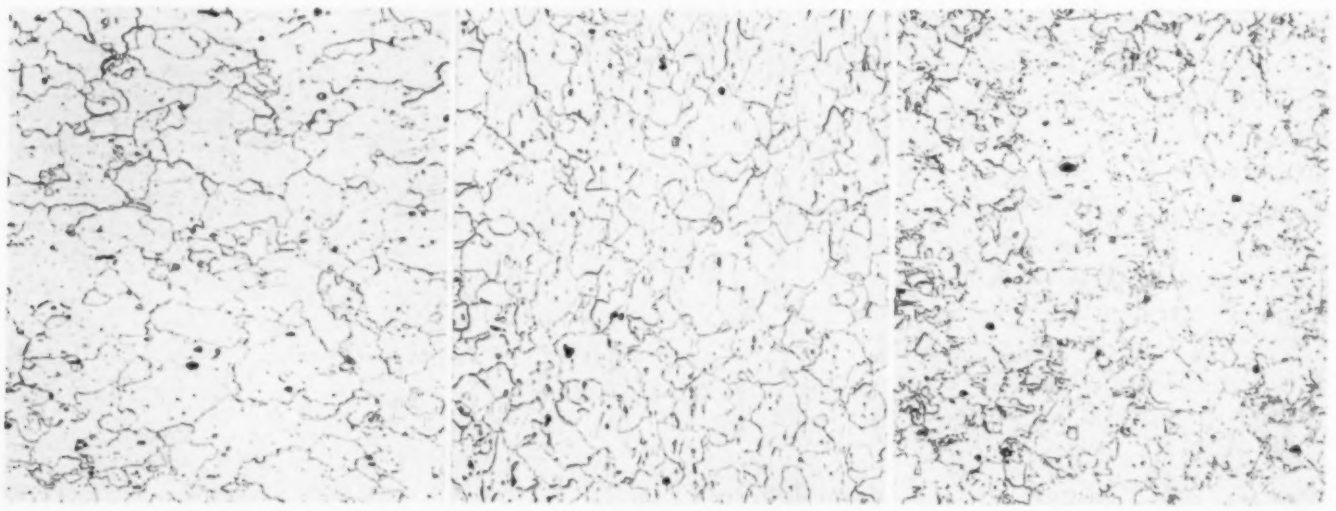
All lots were initially annealed to approximately 70,000 psi. tensile strength before testing for susceptibility to grain growth.

Results are illustrated by the photomicrographs herewith, made by W. S. Colmery, metallographist at the Ellwood Works. Structures of the titanium alloy are shown after heating at 1800° and 2000° F.; structures after the 1600° F. treatment were identical with the former. The columbium alloy's structure after the 1600° F. treatment was similar to that of the original anneal; the 1800° and 2000° F. treatments refined the grain. These tests show that no grain growth developed during the various treatments. The 3-in. tube material from the titanium alloy was coarser grained than the ½-in. tube material, both initially and after each treatment (compare micros at bottom of this and next page), but this difference is due to the great degree of cold work necessary to manufacture the latter.

Tensile properties of the two alloys after conversion into tubular form are listed in the last table. For comparison, similar values for 5% chromium, ½% molybdenum steel *M* are in the same table. The significant features are *(a)* the titanium-bearing or columbium-bearing alloys do not harden materially when air cooled after rolling operations, and *(b)* they can be annealed at lower temperatures than the 5% chromium, ½% molybdenum steel.

Grain Size After 1 Hr. Heating

Temp.	Steel T	Steel C
1900° F.	7 to 8	7 to 8
2000	5 to 8	6 to 8
2100	5 to 8	6 to 8
2200	0 to 5	00 to 8
2300	5 to 1	7 to 3
2400	1 to 5	7 to 3



Treatment 1, Annealed 1425 | 2 Hr. at 1800° F. | 1 Hr. at 2000° F.

Grain Size of Titanium-Bearing Alloy T in 3 x 0.25-In. Tube; Nital Etch; 100 Diameters

Mechanical Properties of the Tube Materials

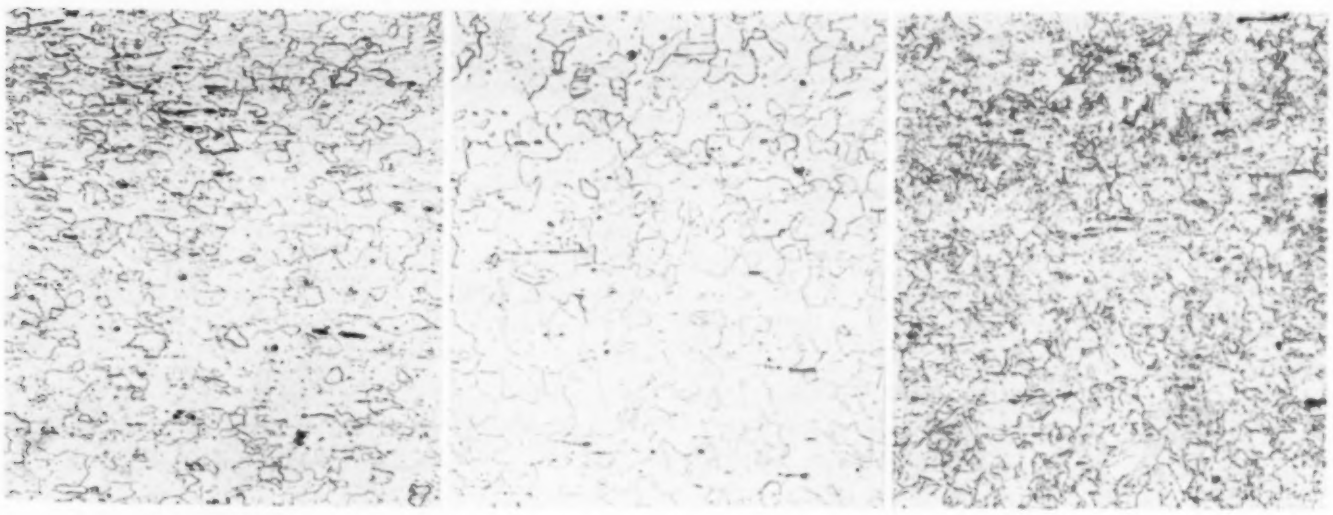
Symbol	Material	Condition of Tube	Size and Treatment*	Tensile Properties			Charpy Impact Ft-lb.	
				Yield	Tensile Strength	Elongation in 2 in.	At 75° F.	At −25° F.
T	Titanium addition	Hot rolled		56,070	78,080	36		
		Hot rolled, annealed	1	53,420	75,990	44	77.1	39.6
		Cold drawn, annealed	1 and 2	39,760	63,630	47		
		Cold drawn, annealed	1 and 3	38,900	63,040	48		
		Cold drawn, annealed	1 and 4	50,520	73,990	36		
		Cold drawn, annealed	5	41,510	69,000	36		
C	Columbium addition	Hot rolled		68,500	95,520	29		
		Hot rolled, annealed	1	56,560	67,870	49	56.7	36.3
		Cold drawn, annealed	1 and 2	49,000	74,120	40		
		Cold drawn, annealed	1 and 3	47,800	73,220	40		
M	5% chromium, 0.5% molybdenum	Hot rolled		128,170	174,700	18		
		Hot rolled, annealed	6	42,440	72,580	42	44.5	33.1
		Cold drawn, annealed	6	39,820	71,540	45		

*1. Annealed at 1425° F. 2 hr., furnace cool to 1200° F.
2. Tube size, 1⅝-in. outside diameter by ¼-in. wall.
3. Tube size, 1-in. outside diameter by 0.148-in. wall.
4. Tube size, 3-in. outside diameter by ¼-in. wall.
5. Annealed at 1325° F., air cooled; tube size ½-in. outside diameter by $\frac{1}{16}$-in. wall.
6. Annealed at 1600° F. 2 hr., furnace cool to 1100° F.

Charpy impact tests made at room temperature and −25° F. showed that the titanium-bearing and columbium-bearing alloys also had better notch toughness.

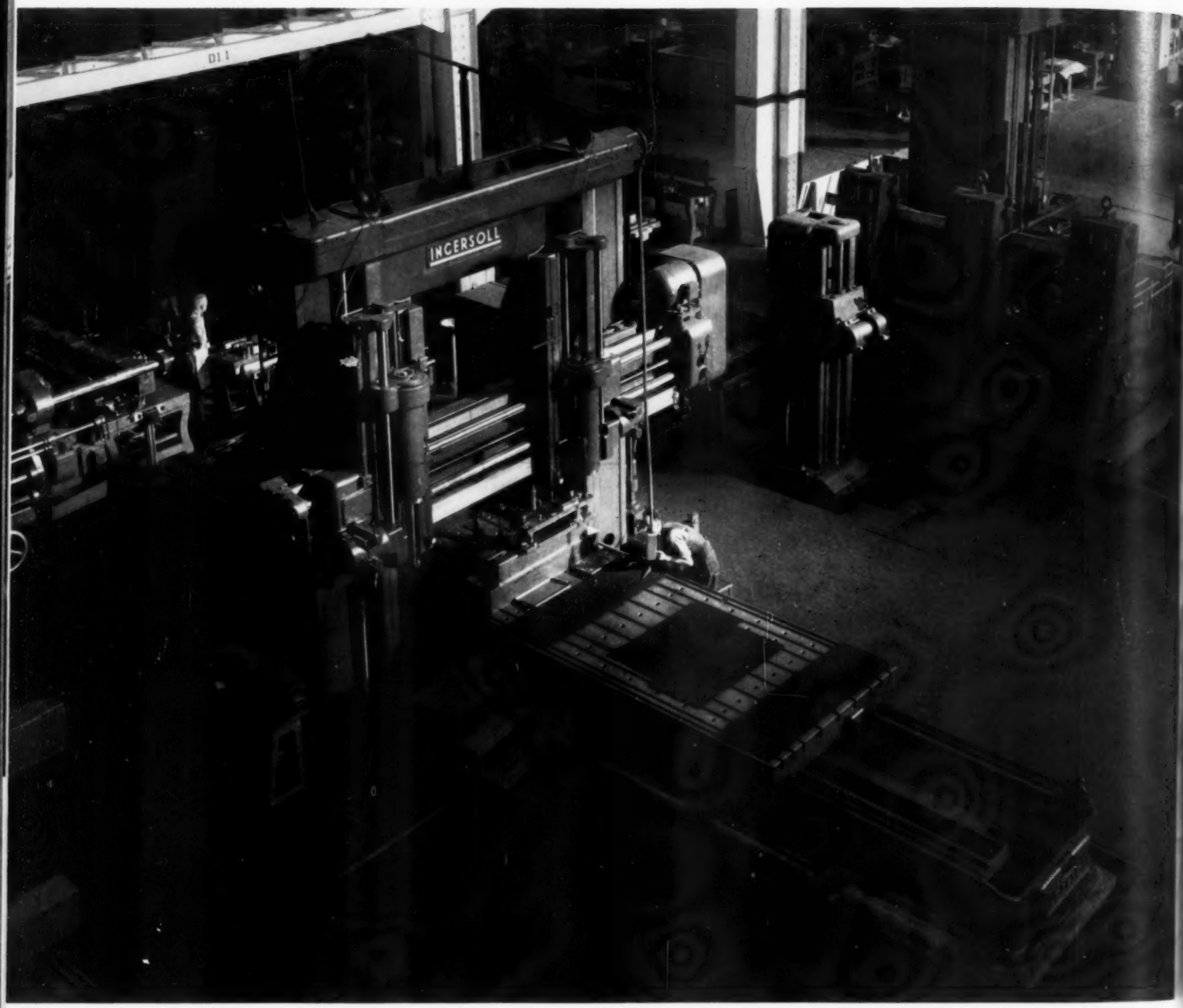
Manipulating tests made on each tube of the various sizes listed just above showed that the materials would flatten wall-to-wall, flange 90°, and bend 180°. Surface inspection, in a pickled and sand blasted condition, showed the tubes to be free from seams and to have a very good surface finish.

Summary and Conclusion — The test procedures show that the materials from the two heats had good oxidation resistance up to 1600° F., were immune to air hardening when air cooled from temperatures up to 1700° F., did not develop grain growth when reheated at temperatures up to 2000° F., responded to ordinary annealing treatments, and had good impact resistance. After conversion into various sizes of seamless tubes, the materials from the two heats had good surface quality, ductility, and manipulating properties. It seems reasonable to assume from the combined results that, with these percentages of alloying elements, satisfactory steel can be produced in the form of seamless tubes to develop the desirable properties described.



Annealed at 1300° F. 2 Hr. at 1800° F. 1 Hr. at 2000° F.

Grain Size of Titanium-Bearing Alloy T in 0.5 x 0.062-In. Tube; Nital Etch; 100 Diameters



Size and Precision

Special "drill press" installed in tool room at Rouge Plant, Ford Motor Co., to drill matching holes in forging and forming dies. The great size is required to care for the largest dies for the body shops. Although these may weigh several tons, they must be brought together in each operation with the highest accuracy — hence extremely close limits in spacing and boring of these holes.

Metal Progress; Page 406

TOUGHNESS—

particularly of toolsteel

By Robert S. Rose
Sales Metallurgist
Vanadium-Alloys Steel Co.
Boston, Mass.

A FEW MONTHS AGO samples of ¼-in. round, annealed carbon steel were submitted to 25 people engaged in the manufacture of steel products with the request that they heat treat them to the condition which each considered would be that of maximum toughness. No stipulations as to hardness or any other physical properties were made — just "maximum toughness". Eighteen of these specimens have been returned and they have hardness values varying from Rockwell C-45 to C-62, some variation in grain size, and other physical properties so different that they could easily be differentiated by any of the commonly used laboratory tests. This was not unexpected nor is it a reflection on the heat treating techniques, but rather serves further to illustrate how futile are the discussions of "toughness", since the word lacks a single concept or real meaning. It might rightly be considered a good subject to avoid but perhaps by mixing a few facts with several opinions a clearer understanding may result.

The samples which were returned might be divided into two general groups which appear to represent two fundamental and distinct concepts of the word "toughness". Translated into definitions they might be:

1. Toughness is the ability to deform before breaking.

2. Toughness is the ability to resist breaking. (This may be better expressed by stating that toughness is the ability of a material to absorb energy without breaking.)

Resisting breakage implies that the material can absorb the imposed load in some manner other than by plastically deforming. Prior to plastic deformation metals accommodate forces to which they may be subjected by minute elastic movements. These elastic movements continue up to the elastic limit and this point (which in toolsteel is substantially the same as the proportional limit) is largely determined by the hardness. Therefore, loads which are beyond the elastic limit of soft steel and would be absorbed by both elastic and plastic deformation might be less than the elastic limit of a harder steel and consequently be absorbed altogether by its elastic movements. Definition No. 1 therefore conceives only the degree or amount of plastic deformation prior to failure while definition No. 2 introduces the load or stress necessary to initiate the deformation. The latter appears much the more practical concept, since rarely are large degrees of flow or deformation permissible with hardened toolsteels.

Sometimes our conception of a word is obtained by a description of what it is *not*, or from words which we consider opposites. Usually the word "brittleness" is thought of as being opposite to toughness. This is not necessarily true, as a brittle material may be either very weak or very strong. The word "brittle-

ness" implies that a material shows little or no plasticity to fracture, and the factor of elasticity is not clearly implied as to degree.

As implied by definition No. 2, the word "toughness" appears to represent the product of the load times the deformation, which in itself is altogether insufficient to define a useful property unless complemented by other individual requirements such as hardness or yield strength. This can be illustrated by a so-called stress-strain diagram in which the load applied (stress) is plotted as the ordinate and the corresponding deformation (strain) as the abscissa. Thus in the first diagram a load L will result in the deformation AC; and the load at fracture will result in the total deformation AD. The toughness of the specimen might be represented by the area under the curve, which is actually the amount of energy absorbed by the sample to fracture (when the unit load beyond the yield point is figured on the reduced area). The product of the stress and the strain is represented by the area of the rectangle $ADFG$, and is a first approximation of the area under the curve ABF. It may be remarked that the stress-strain curve can be plotted, and it has the same implications whether the load is in tension, is transverse as in a beam, or is in torsion.

One often hears the words "brittle" or "tough" used in describing the fractures of specimens or parts broken in testing machines or in service. That such "brittle" fractures or "tough" fractures can be obtained at will from many types of material by variation in loading is not generally recognized. An analysis of the stress system developed by the various types of loading, together with the strength properties of steel in different directions, will explain the different appearances of the fracture.

The cohesive strength of steel is the resistance of the atom planes to separate or the resistance to cleavage or pulling apart without deformation of any sort. When fracture occurs before deformation has taken place the fracture has the so-called "brittle" appearance. However, most crystalline materials, such as steel, have the ability to flow or deform under load, which is accomplished through the gliding or slip of atom planes on each other, within the crystal. Movement of this sort is called "shear" and the resistance of the crystals to such internal slipping is called "shear strength". When steel parts shear prior to failure, the fractures are generally called "tough". Therefore, the distinction between "tough" and "brittle" fractures is partly dependent on the amount of shear that precedes fracturing.

Now it will be recalled that toughness was conceived of as a product of two components, one of which was the deformation; since no deformation is possible without shear, its contribution to toughness is obvious. Whether a material of selected strength will shear prior to fracture is not determined so much by the hardness as by the stress system developed — that is, whether the shear strength is exceeded prior to the cohesive strength. If the shear strength is first exceeded the part will deform; if the cohesive strength is reached first it will cleave and be called brittle.

Thus, while the properties of a steel are fixed by a specific heat treatment and hardness, the indications to be drawn from the fracture imposed by various testing methods will be different, since loading in tension, torsion and flexure induces a different ratio of cohesive (normal) stress to shear stress.

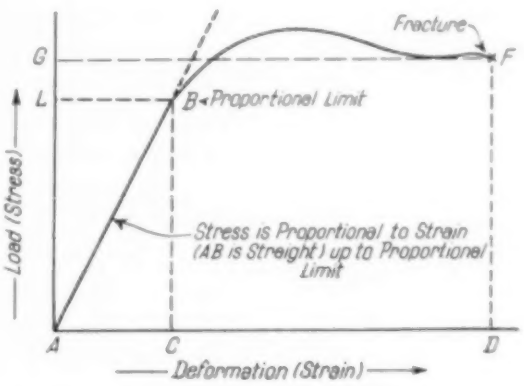
Determination of Toughness

There are quite a variety of tests employed to determine toughness and each has some merit. But before discussing them it is significant to point out that the accepted definition of hardness is "the resistance to plastic deformation" and, as a consequence, one real object of hardening is to increase the resistance to this deformation or permanent setting. Since deformation or setting is accomplished only by shear, the conclusion is inescapable that by hardening we mean increasing the shear strength, and that variations in hardness represent variations in shear strength. Increase in hardness presumably also increases the true cohesive strength although its direct determination has not been made. The most likely hypothesis is that the shear strength increases faster than the cohesive. Hardening then is a deliberate attempt to impede plastic deformation, one of the components of toughness.

1. *Tension and Tension Impact* — In this test the greatest cohesive (normal) stress acts on a plane perpendicular to the axis of the specimen being pulled; the greatest shearing stress occurs on a plane 45° to the axis. It happens that the greatest normal stress developed is exactly twice the greatest shearing stress. Thus to be ductile in this test the cohesive strength must be more than twice the shearing strength, otherwise the cohesive strength will

be exceeded first and cleavage will result. Up to fairly high speeds of loading (which vary with materials and treatments) the indications of the tension impact and the static tension can be correlated. As outlined in the discussion, above, of the stress-strain curve the area under the curve of the static test is most generally used to evaluate toughness.

2. *Torsion and Torsion Impact* — An analysis of the stress system of this test shows that the maximum normal stress developed is just equal to the maximum shearing stress. Thus if the cohesive strength of a material were only 1½ times the shear strength, the material would still be ductile in this test, while in the tension test the limit of cohesion of that metal would be reached and rupture without deformation would occur. The indications of the static torsion and the torsion impact test appear to be almost identical if proper allowance be made for the increment of energy dissipated in the static test in the form of heat. Torsion tests have indicated peculiar and high toughness values (in straight carbon steels with specific tempering treatments) not shown when test pieces are loaded in tension, transverse or flexure. An example is given in the second curve, page 410. Since the high peaks in the torsion impact values are followed by lower values at a lesser hardness and higher tempering temperatures (indicative of a reduction in shear strength), they cannot be reconciled on this basis. If a specific microstructure, embodying minute carbides precipitated in the tempering range immediately higher than that which produces the high peaks, has an adverse effect on the cohesive strength, the shape of the torsion impact curve is understandable. Under such circumstances the ratio of cohesive to shear strength is reduced, which results in earlier cleavage and less deformation. Incidentally it has been shown in both the static and impact torsion test that the angular deformation is less in this range immediately following the peak toughness. A similar decrease in angular deformation is obtained in several types of tool-steel simultaneous with the transformation of the retained austenite (solid solution), which results in the precipitation of a new phase and this appears to reduce the cohesive strength. However real these values are in torsion, the effect on the cohesive strength is not sufficiently pronounced to change the gradual increase of toughness with tempering temperature, as indicated by the tension test and the un-notched Charpy test.



Typical Stress-Strain (Load-Deformation) Curve for a Hard Steel That Exhibits no Sudden Elongation or Yield Point, and That Has Comparatively Small Plastic Deformation Before Rupture

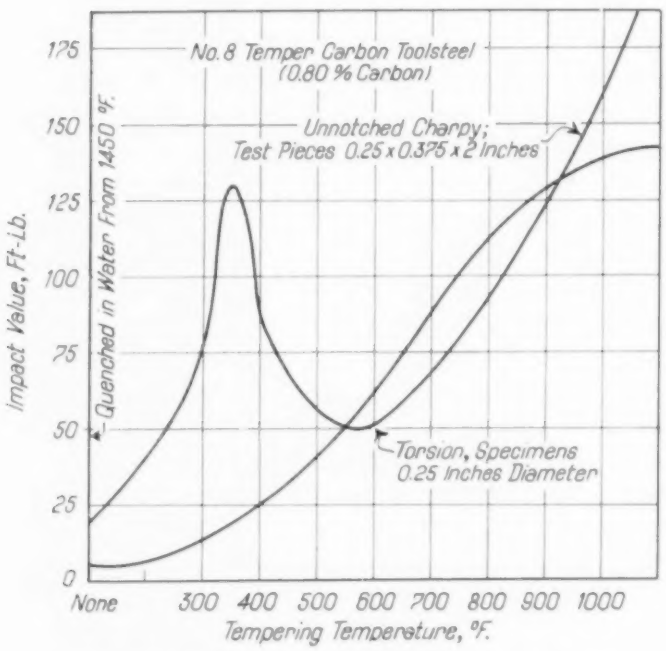
3. *Notched and Un-Notched Charpy and Izod Tests* — No precise stress analysis is possible in these impact tests. It is known, however, that (in un-notched specimens) the maximum normal stress developed is greater in comparison with the shearing stress than it is in the tension test. Thus if the cohesive strength of a steel sample were slightly more than twice its shearing strength, it would be brittle in the impact test while ductile in the tension test and of course in the torsion test. These tests also fail, since only the product in foot-pounds is indicated, to distinguish properly between materials combining high strength and low ductility and those of low strength and high ductility. They do not indicate the amount of energy absorbed up to the inception of a crack — only the total amount of energy absorbed in deforming and finally fracturing. Moreover there is no real understanding of the dimensional factors, since small test specimens give values not at all in agreement with large specimens.

Notching produces a different stress system for every different notch. An increase in the depth or severity of a notch increases the normal (cohesive) stress developed by a given load at the base of the notch, in comparison with the shearing stress. As a consequence a material may be brittle with one type of notch but tough with another. The notched bar Charpy and Izod tests are of no value in the testing of steels of high hardness, but with moderately soft and soft materials it will distinguish between steels and various heat treatments of the same steel that the other tests could not differentiate. By increasing the notch

severity, differences in impact values (expressed in foot-pounds) of over 200% have been indicated in such cases. When Izod and Charpy specimens have mild notches, the cohesive strength of the softer steels is so high in proportion to the shear strength that insufficient cohesive stress is developed to make any distinction, specimen to specimen. By increasing the severity of the notch, with the attendant increase of cohesive stress, a point is reached where some steels and some treatments will indicate brittleness through lack of shearing ability, and some will continue to be tough. Since the values obtained from the testing of hard steels which have high shear strength are so low and so erratic, this method is not considered applicable to such steels.

Correlation of Toughness Tests

In light of the previous discussion it is probably needless to say that there is no substantial reason why toughness values derived from tension tests, torsion tests, Charpy tests and transverse tests should be similar. They *may* be, under conditions where the cohesive strength is, say, four times or more the shear strength; these conditions, however, never obtain with steels of high hardness. It will be recalled that in the torsion test the cohesive (normal) stress developed is just equal to the shear stress; in the tension test the cohesive stress is twice the shear stress; in the so-called standard Charpy test the cohesive stress is still higher — let us say, three times the shear stress. The moderately soft ductile steels, as mentioned above, with cohesive strength four times their shear strength, would show at least fair toughness in all the tests. If, however, the severity of the notch in the Charpy type specimen were increased to the point where the cohesive stress developed was greater than four times the shear stress, this same steel would appear to be brittle. The same critical point in stress relationship could be developed, by change of the hardness, so as to fall between the torsion and tension test (or between the tension and standard Charpy test) so as to produce utterly different results between them.



Curves by Courtesy of Bethlehem Steel Co. Showing Diverse "Toughness" Values for a Plain Carbon Toolsteel Tempered at 350° F., Depending on the Type of Impact Test

All this serves to emphasize the fact that the quality of usefulness of a steel or treatment is not defined by a single type of test. It should serve to indicate the futility of anticipating service results on the basis of one test, most particularly if the service imposes loads unlike that of the test and where the cohesive stress developed is greater in relation to the shear stress. Even if we wanted to be more cautious and use the results of more than one test, it would still be necessary to read between the lines. An example is given in the second diagram, showing that the toughness of 0.80% C straight carbon toolsteel after various tempering treatments is very dissimilar, as revealed by static or impact torsion tests and un-notched Charpy tests. Laboratory tests of the type discussed are of value in indicating gross effects, but are not, in the opinion of the writer, of adequate sensitivity to permit a correct selection of materials or treatments unless a direct correlation has been made with the material in actual production.

In conclusion a list may be made of

Factors Which Appear to Affect Toughness Adversely

1. *Internal Stress.* This has been often used to account for failures for which no other explanation seemed available. Despite the fact that the measurement of internal stress is difficult or in most instances impossible, ample evidence of it has been seen by everyone who has seen a die or tool crack in heat treatment. It appears to have a two-fold effect — *(a)* to detract by its quantitative amount from the

strength of the material and *(b)* to act as an internal notch in increasing the ratio of cohesive to shear stress. Drastic quenching, temperature gradients such as are induced in severe grinding, and the rapid heating of quenched steel induce internal stress to abnormal degrees. It should be remembered, of course, that in some instances internal stress is in a favorable direction, and at that region is additive to the strength of the material.

2. *Cold Work.* This acts to detract from the available plastic deformation.

3. *Coarse-Grained and Overheated Structures.* These conditions presumably act to decrease the cohesive strength, but may also accentuate internal stress.

4. *High Hardness.* Attendant to high hardness is, by definition, high resistance to deformation. In addition, the development of high hardness creates such high degrees of internal stress that minute discontinuities sometimes develop. These are seldom healed by subsequent tempering and of course decrease the cohesive strength. It is expedient, therefore, when applications do not demand high hardness, to avoid the high Rockwell hardness ranges altogether. This can be accomplished by less drastic quenching or by restricting the carbon content.

5. *Abnormal Segregations of Both Metallic and Non-Metallic Inclusions.*

On the other hand we have the

Favorable Factors

1. *Stress Relief.* The antithesis of items No. 1 and 2 above, and best achieved by less drastic quenching and adequate temperings.

2. *Fine Grain.* The connection between fine grain and "toughness" has been known for so long it is part of the traditional lore of the fine steel maker. Some scientific explanations have been developed, but for our present purposes it is merely necessary to state the fact.

3. *Alloy Content.* One of the important contributions of the alloy, other than its effect on hardenability, is in the reduction of rate of softening with tempering temperature. To be consistent with the necessary hardness, straight carbon steel may not be tempered over 350° F., whereas a steel of similar carbon content with as little as 2% alloy can produce equal hardness after a 500° draw. The use of the higher tempering temperature clearly lessens the internal stress and contributes to higher toughness.

LONG GRAINED OR SHORT?

By Martin Seyt

WHAT SCION of metallurgy has not heard the graybeards of his youth solemnly discoursing about long grained copper? Now comes a man who tries to find out what it is and how you get it. Last year, L. Northcott showed that small additions of various metals each had an individual effect on the crystal growth of copper.

This year in the same *Journal* of the Institute of Metals, Dr. Northcott deals with binary alloys of copper, all made under uniform laboratory conditions. The idea, it appears, was to find out what influence on crystal growth the alloy itself would have. It had plenty! Here is the story: With a pure metal, or with an alloy that freezes at a constant temperature, columnar crystals can grow as long as your arm. But if the alloy starts freezing at one temperature and finishes at a much lower one, columnar crystals are not favored. It is as simple as that.

Alloys of copper, each separately, with zinc, aluminum, phosphorus, magnesium, manganese, nickel, lead, tin have been explored; faithfully and inversely, the length of the crystals follows the width of the freezing range. Addicts of exotic design should note the pictures. For example, with copper-zinc, as the zinc increases the crystals are partly columnar, partly equi-axial, until the zone of about 40% zinc is reached, where the freezing range is short and the metal is entirely columnar. Tin bronze, with a rather wide freezing range, runs mostly to small, equi-axial grains, although the rule doesn't work as well with tin-copper as with other alloys. Columnar crystals of aluminum-copper are particularly broad. Noting this, the author digresses a trifle to show that aluminum confers this characteristic on other alloys to which it is added.

Having shown that the question of grain size is very simple, Dr. Northcott then proceeds to discuss the results and leaves the impression that there is something exceedingly complex about it after all. To make things worse, it is suspected that the author thinks so too! But we admire his method of running down one factor at a time, and presenting it to those who find nourishment in that kind of a diet.

LEAD-BEARING STEELS

control of possible health hazards during fabrication

By James W. Halley & Edwin Dudley Martin
Metallurgical Department
Inland Steel Co., East Chicago, Ind.

USE OF ANY MATERIAL containing lead requires a consideration of the health hazard that may be involved. Since Ledloy steels contain only ¼ of 1% lead, compared to 10% in some brasses, and 50% in solders and paints, we would expect no health hazard under most conditions. This actually proves to be the case. However, these facts should not convince us that no hazard exists under any circumstances.

The metallurgical department of the Inland Steel Co. has carried out a detailed investigation to determine under what conditions a hazard may exist, and what methods of control are necessary.

Lead has long been recognized as toxic. An extensive literature on the subject is available, as noted in the article by one of the present authors on "Control of Lead in the Steel Plant" in METAL PROGRESS, May 1939. It has been found that the human body normally absorbs and eliminates a certain amount of lead. The rate at which lead can be eliminated is limited. Under favorable conditions the body can store lead without detrimental effects. However, this storage capacity is limited and the lead may be released by a change in general health, so that it is necessary to keep the average lead intake at a level below the ability of the body to eliminate it. Lead intake is nearly all through the lungs from lead dust or fume in the air.

The proper control of any possible health hazard from lead therefore requires that the lead concentration of the air breathed be maintained below some safe maximum. This maximum is called the "threshold value" and has been determined by various investigators as a value between 1.5 and 5 mg. of lead in 10 cu.m. of air. A volume of 10 cu.m. is used because it is the volume of air breathed in 8 hr. by a man at reasonably hard labor. These values were obtained using the "impinger" method for sampling the air, wherein the air is drawn through one or more bottles containing an absorbent such as dilute nitric acid; the stream of air passes down a tube in the bottle and impinges on the wetted surface at the bottom which aids in wetting the particles of fume and dust carried by the air. This type of apparatus does not catch the finest particles of fume (under about 0.5 microns or 0.00002 in.). It is probable that the lungs do not retain these very fine particles, being breathed out again like the fine particles in cigarette smoke. Consequently the impinger method is believed to give values of lead concentration representing the true amount of lead absorbable by men breathing the air, and it has been used by investigators in establishing "threshold" values. An electrostatic precipitator will catch substantially all of the particles and when used following the impinger

will give an indication of the size distribution of particles in the air as well as its total lead content.

We have used a threshold value of 3 mg. of lead in 10 cu.m. of air as the best established value. The lowest value that has been given is 1.5 mg. in 10 cu.m. of air. It seems quite probable that 5 mg., which has been recommended, is too high.

The health hazard problem in connection with lead-bearing steels consists in determining the rate at which lead is released to the air in any type of fabricating operation. Knowing the rate at which the lead is released and the ventilation surrounding the operation, it is a simple matter to calculate the concentration. If such calculations show concentrations above the threshold value, either the ventilation should be increased or an exhaust system provided.

The facts concerning release of lead during various operations were determined by carrying out the complete operations in a closed chamber through which air was passed at a measured rate.

The arrangement of the equipment is shown in the drawing below. The blower is capable of delivering 110 cu.ft. per min. at 4-in. water pressure. The volume of the air going into the booth is measured by the inclined manometer across the orifice. The volume of exit air is measured by an anemometer which was calibrated against the orifice with the booth closed. An interior fan is directed against the stream of incoming air and prevents dead air spaces from developing in the booth. The operator inside the booth wears an air-fed respirator and the volume of air to the respirator is measured by a displacement meter. The exit air is sampled for lead as it issues from the anemometer, by drawing the air through four impinger bottles in series and then through an electrostatic precipitator. The blower is placed some distance from the booth and under an open window to prevent the recirculation of lead leaving the booth.

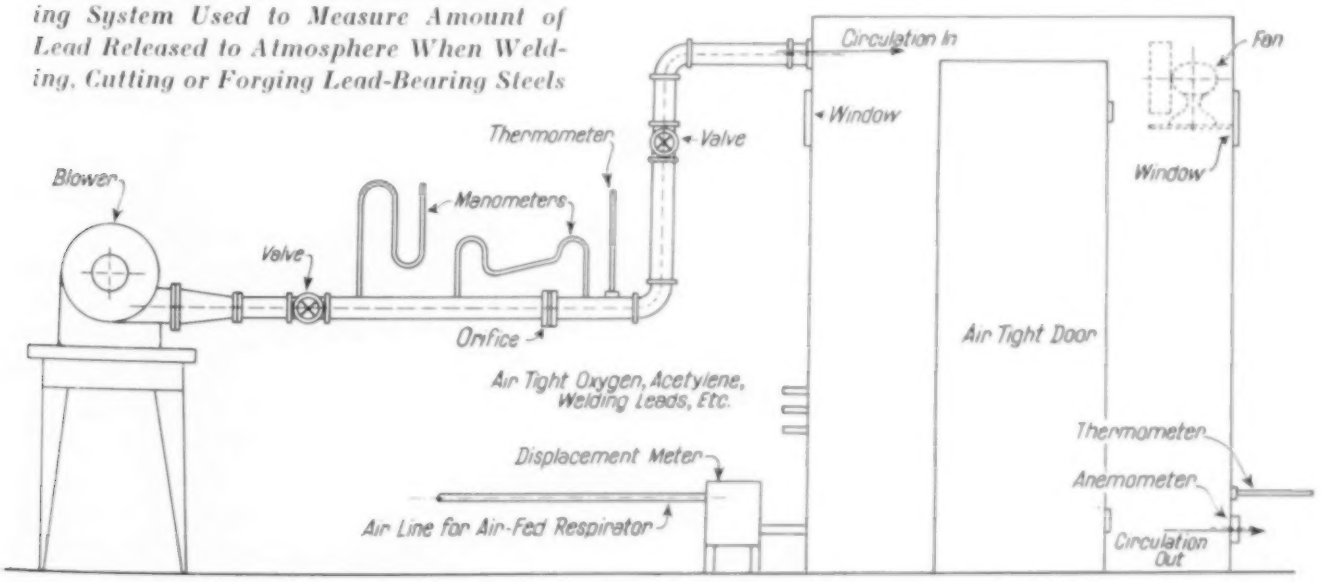
Arc Welding 0.5-In. Plate

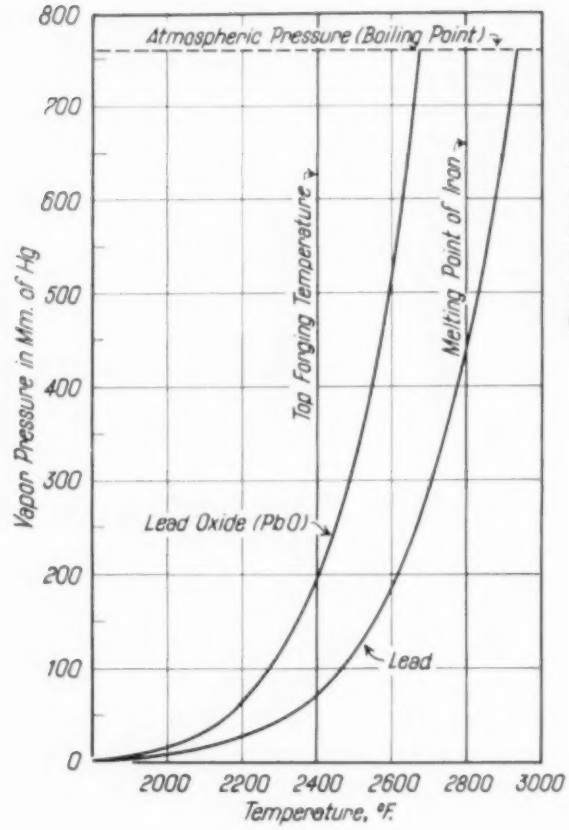
Steel: Ledloy 1025
Weld: Fillet weld with $\frac{5}{32}$-in. electrode, heavily coated
Total time of test: 101 min.
Sampling time: 64 min.
Air velocity: 26.70 cu.ft. per min.
Lead caught in impinger: 0.0000904 g. per cu.ft.
Lead caught in precipitator: 0.0000151 g. per cu.ft.
Length of weld made: 16 ft.
Area of base metal fused: 0.0176 sq.in.
(found by etching samples cut across weld)
Lead in base metal fused: 0.999 g.
Lead coarse enough to be caught in impinger: 0.243 g.
% of lead in base metal fused caught in impinger: 24.3%
Lead caught in precipitator: 0.041 g.
% of lead from base metal, caught in precipitator: 4.1%

In making a test the booth is closed, the rate of air flow adjusted and the operator begins the operation being studied. The air is not sampled until at least four times the volume of the booth has passed through. After this flushing process, sampling is started and continued to the end of the run.

Results of a typical experiment on the arc welding of a 1025 steel containing 0.23% lead are shown in the tabulation above. A series of runs on arc welding gave good checks, the average release being 29% of the lead in the fused metal caught in the impinger and an additional 6% caught in the precipitator.

Sketch of Air-Tight Cabinet and Ventilating System Used to Measure Amount of Lead Released to Atmosphere When Welding, Cutting or Forging Lead-Bearing Steels



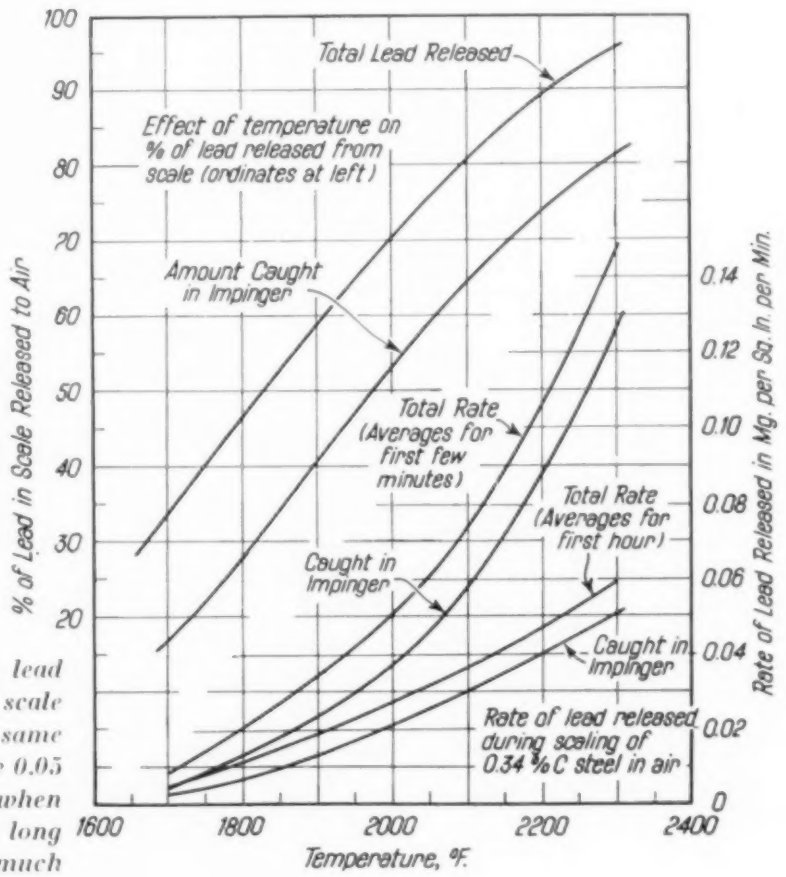


Vapor Pressure of Lead and Lead Oxide Increases Very Rapidly With Temperatures Above 2500° F. Data for lead from International Critical Tables; for lead oxide from Metall und Erz, *1929, p. 269. Top forging temperature from* Recommended Practices

Oxygen cutting released a much greater proportion of the lead to the air; 17% of the lead in the steel is caught in the impinger and an additional 41% is caught in the electrostatic precipitator. The greater lead release during oxygen cutting is a result of the high vapor pressure of lead oxide. (The vapor pressures of lead and lead oxide at high temperature are shown in the adjoining curves, which also show the tremendous importance of temperature on the vapor pressure and consequently on the amount of lead released from molten or oxidized Ledloy steels.)

Tests on acetylene welding did not give consistent results and the amount of lead released to the air could not be correlated with the amount of base metal fused. It was found that the comparatively slow heating by the torch caused appreciable quantities of scale to form adjacent to the weld and that lead was released from this scale. The amount of scale formed near the weld was affected by all of the factors controlling the rate of heating — thickness of plate, size of tip, gas pressure, and technique of the welder. It was therefore impossible to get any definite figures, but the rate of lead release was always considerably less than for arc welding a similar joint.

Lead released during scaling was measured in another series of tests. Short cylinders of Ledloy steel were heated in a small high frequency furnace placed inside the booth. The cylinders were supported on a pedestal inside the furnace coil so that scaling was uniform all around, except at the end of the cylinder. In order to make the process a continuous one, each cylinder was heated for a definite length of time, removed and replaced by a cold cylinder. A 40-sec. heating time brought the cylinders to 2300° F.; 20 sec. to take the cylinder out and replace it with a new one gave a 1-min. cycle. In one series of these tests the cylinders were



Amount of Lead Eliminated From Scale as it Varies With Temperature. Upper curves show, for instance, that at medium forging temperature (2000° F.) 70% of the lead escapes and 30% of the lead is retained in the scale that forms. Lower curves show that at the same temperature a rapidly scaling steel will release 0.05 mg. of lead per sq.in. of surface in a minute when the scale is thin and just forming; over a long heating the average rate is about half as much

Computation for Oxygen Cutting

Cutting 1-in. low carbon plate; 0.25% lead.
Cutting speed, 15 in. per min.
Width of kerf, 0.10 in.
Actual cutting time, 40% of total time.
Ventilation, 400 cu.ft. per min.
Volume of metal removed in 1 min. of continuous cutting, $0.10 \times 15 = 1.5$ cu.in.
Actual volume of metal removed,
40% of $1.5 = 0.6$ cu.in. per min.
Weight of metal removed,
$0.6 \times 0.283 = 0.170$ lb. per min. or
$0.170 \times 453.6 = 77.2$ g. per min.
Lead in metal removed,
$77.2 \times 0.0025 = 0.193$ g. per min.
Lead released into the air that would be caught in impinger,
$0.193 \times 1000 \times 0.47 = 90.6$ mg. per min.
Volume of air per min.,
$400 \times 0.0283 = 11.3$ cu.m. per min.
Lead concentration of air,
$90.6 \div 11.3 \times 10 = 80.2$ mg. in 10 cu.m. air

This is far above the threshold value and indicates that the ventilation should be increased or an exhaust system provided. The amount of ventilation required to maintain a concentration below the threshold value would be:

$90.6 \times 10 \div 3 = 302$ cu.m. per min.,
or $302 \times 35.3 = 10{,}660$ cu.ft. per min.

It would be impractical to maintain this great an air change, so a local exhaust system should be used.

Computation for Arc Welding

Fillet weld between low carbon plates; steel contains 0.25% lead.
$\frac{3}{16}$-in. heavy coated electrodes
Rate of welding, 15 ft. per hr., (3 in. per min.)
Area of base metal fused (found by etching cross-section of weld), 0.015 sq.in.
Actual time of welding, 50% of total time.
Ventilation, 400 cu.ft. per min. (or 11.3 cu.m.)
Volume of base metal fused in 1 min. of continuous welding, $3 \times 0.015 = 0.045$ cu.in.
Actual volume of base metal fused,
50% of $0.045 = 0.0225$ cu.in. per min.
or $0.0225 \times 0.283 = 0.00636$ lb. per min.
or $0.00636 \times 453.6 = 2.88$ g. per min.
Weight of lead in base metal fused,
$2.88 \times 0.0025 = 0.0072$ g. per min.
Lead released into the air that would be caught in the impinger,
$0.0072 \times 0.29 = 0.00209$ g. per min.
Lead concentration of air, $(2.09 \div 11.3) \times 10 =$ 1.85 mg. in 10 cu.m. of air

This concentration is below the threshold value and without some change in conditions we would not expect a health hazard.

water quenched so that most of the scaling occurred at the high temperature and in another series they were air cooled so that scale formation continued to lower temperatures.

These tests demonstrated that the release of lead changes very rapidly with temperature. Results varied, depending upon the accuracy of centering the cylinders in the furnace coil and the amount of scale adhering to the pedestal, because the maximum temperature reached by the sample decreased rapidly as the sample was moved from the center of the coil. The greatest amount of lead released during any one run was 67.6% of the lead in the steel that turned to scale; 40.6% was caught in the impinger and an additional 27.0% in the precipitator. The smallest amount of lead released was obtained on a run in which the samples cooled in the air. Of the lead previously existing in the steel which was turned to scale, 6.5% was caught in the impinger and an additional 7.8% was caught in the precipitator.

These tests showed that the lead released was always considerably less than the quantity of lead in the metal turned to scale, and that at the lower temperatures a smaller proportion of the lead released was caught in the impinger.

In order to determine this effect of temperature with some precision, samples were held at elevated temperatures in a muffle furnace. After scaling, the loose scale was broken from the samples and analyzed for lead and iron. The samples were then pickled (using an inhibitor) and the pickling solutions analyzed for lead and iron. The samples were weighed before scaling and after pickling, and the percent of lead released from the scale at each test for a given temperature was calculated. The results are shown in the upper curve of the last diagram. Samples heated for various periods of time showed that the percent of lead released from the scale is practically independent of time and the amount of scale formed. The lower parallel curve was determined by comparing the lead caught in the impinger with that caught in both the impinger and precipitator (in the experiments made in the booth).

The *rate* of lead release from heated Ledloy steel is dependent both upon the percent of lead released from the scale that is formed and the rate at which the scale forms. The rate of scale formation at any temperature is dependent upon both the composition of the atmosphere, the composition of the steel, and the amount of scale already on the sample. The most rapid formation of scale occurs on a 0.30 to 0.40% carbon steel when heated in air and before an appreciable amount of scale has formed. The upper two curves in the lower

right set (page 414) represent this rate of lead release; samples were in the furnace for 20 min. and at furnace temperature for about 10 min. These curves represent the most rapid rate of lead release to be expected in heating or forging operations.* The two lower curves represent the rate of lead release during scaling for longer periods of time in which the scaling rate has been cut down by the presence of scale already formed on the steel.

Under normal heating conditions the rate at which lead is released will be lower than that shown by any of these curves because most heating furnaces use an open flame and in them the products of combustion surround the steel billets and materially reduce the scaling rate. The scaling rate changes so rapidly with small changes in air-fuel ratios that it is impossible to give definite figures.

Equipment During a Test on the Effect of Welding. Sampling equipment at the right was explained in METAL PROGRESS, *May 1939*

*The following references give information on the rate of scale formation under various conditions and will be of assistance in studying the rate of lead release:

Feiser: Über die Flüchtigkeit der Oxyde von Blei, Cadmium, Zinc, und Zinn; *Metall und Erz*, v. 26, 1929, p. 269.

Murphy, Wood and Jominy: Scaling of Steel at Elevated Temperatures by Reaction with Gases and the Properties of the Resulting Oxides; *Transactions*, A.S.S.T., v. 19, 1932, p. 193.

Clair Upthegrove and D. W. Murphy: Scaling of Steel at Heat Treating Temperatures; *Transactions*, A.S.S.T., v. 21, 1933, p. 73.

Cleaves and Thompson: The Metal Iron. Alloys of Iron Monographs. McGraw-Hill, 1935.

Review of Oxidation and Scaling of Heated Solid Metals; Department of Scientific and Industrial Research, H. M. Stationery Office, London, 1935.

Sample Calculations

Knowing the rate of lead release under various heating conditions, a simple calculation for any given operation will show whether or not a hazard exists under the prevailing conditions of ventilation. If the concentration of lead is found to be above the threshold value, the increase in ventilation necessary to reduce the lead concentration below the threshold value can be calculated. When the calculations show that an impractical amount of ventilation is necessary the fumes should be removed at their source by an exhaust system. The latter method of control requires the handling of much smaller quantities of air than increasing the ventilation in the working area; inexpensive, portable machines for removing welding fumes are made by several manufacturers of welding equipment and would be equally adaptable to other operations. Some sample computations are given on pages 415 and 417.

General Considerations—In calculating the rate of lead release, the average time that the operation is carried on should be used. The threshold value is based upon constant exposure of a man for 8 hr. out of 24, and short exposures to concentrations above the threshold value are permissible if they are balanced by sufficiently long periods at lower concentrations.

Ventilation is one of the most difficult items to determine. In the sample calculations a value of 400 cu.ft. per min. has been used. This corresponds to a velocity of 1.14 miles per hr. through an opening 2 ft. square, and is probably considerably lower than will be found in most industrial buildings.

The rate of lead release below 1800° F. is so low that there is practically no possibility of a hazard during heat treating operations.

When the fumes from welding or from

heating furnaces are exhausted or passed into flues, the only lead to be considered is that which escapes. A high concentration of lead in the exhaust system itself is desirable, as it indicates that only small quantities of air must be moved to keep the lead concentration low in the working area.

The most rapid rate of lead release is caused by oxygen cutting, and in most cases calculation will show that an exhaust system is needed, or that the work should be done out of doors.

The rate of lead release from the base metal fused during oxy-acetylene welding is very nearly the same as for arc welding. There is an additional source of lead entering the air from the steel adjacent to the weld, which is usually heated high enough so that appreciable scale forms and some of the lead in this scale is

Computation for Forging

Conditions: A forging weighing 20 lb. with a final surface area of 200 sq.in. is 20 sec. under the hammer, and is being made at the rate of 70 per hr. Temperature under hammer is 2000° F. at start and 1800° F. at finish. Ventilation near the hammer is 400 cu.ft. per min. (11.3 cu.m. per min.). Over-all scale loss is 2%. Heating is by oil, using 19 gal. of oil per hr.; the furnace temperature is 2200° F.

This calculation should be divided into two parts. The lead release under the hammer and the lead release in the furnace can best be considered separately.

Lead Release Under the Hammer

Rate of lead release at 1900° F. from middle curves in the figure on page 414 is 0.023 mg. per sq.in. per min.

Per cent of total time the steel is under the hammer is $20 \times 70 \times 100 \div 3600 = 39\%$

Rate of lead release for the entire area of the forgings, $200 \times 0.39 \times 0.023 = 1.80$ mg. per min.

Lead in 10 cu.m. air, $(1.80 \div 11.3) \times 10 = 1.59$ mg.

This is well below the threshold value.

Lead Release During Heating

Practically all the scaling occurs in the furnace and the scale probably reaches furnace temperature

Weight of iron scaled at 2200° F. in furnace (from scale loss noted in "Conditions")
$(70 \times 20 \times 0.02) \div 60 = 0.466$ lb. per min.
or 216 g. per min.

Lead released from scale in furnace (top curve, page 414)
$216 \times 0.0025 \times 0.77 = 0.416$ g. per min.
(416 mg.)

Volume of flue gases at 2200° F. from perfect combustion of 19 ÷ 60 gal. of oil will be 2250 cu.ft. per min., or $2250 \times 0.0283 = 63.7$ cu.m.

The lead content of this flue gas would be
$(416 \div 63.7) \times 10 = 65.3$ mg. lead per 10 cu.m.

This is far above the threshold value but of course flue gas cannot be breathed because of its composition and temperature.

The required dilution of flue gas can be calculated from both the amount of air required to reduce the temperature to a reasonable value and the amount of air required to produce a composition that can be breathed.

Considering the temperature first; the weight of flue gas would be 59.8 lb. per min. and its specific heat is 4.32 B.t.u. per lb. To reduce the temperature to 90° F. would require the removal of $59.8 \times 4.32 \times (2200° - 90°) = 544{,}000$ B.t.u. per min.

Air initially at 68° F. will absorb 5.72 B.t.u. per lb. during heating to 90° F.; the amount of air necessary to lower the temperature of the hot flue gas to 90° F. would be
$544{,}000 \div 5.72 = 95{,}000$ lb. of air per min.
$95{,}000 \div 0.070 = 1{,}355{,}000$ cu.ft. of air per min. at 90° F.

The original products of combustion, when cooled to 90° F., will have a volume of
$(2250 \times 550) \div 2660 = 465$ cu.ft. per min.

The diluted flue gases at 90° F. would have a lead concentration of
$416 \times 10 \div (1{,}355{,}465 \times 0.0283) = 0.0115$ mg. in 10 cu.m.

We obviously do not get this much dilution. The quantities of air required are too large. What actually happens is that the flue gases pass out of the building at considerably higher temperatures, carrying the lead they contain with them. The calculation does show us that lead in the flue gas after cooling to endurable temperature by dilution is of minor importance.

Considering the composition, the original flue gas would have the following approximate composition by volume: CO_2 13.1%, CO 1.0%, N_2 73.7%, and H_2O 12.2%. For safety the CO concentration should not exceed 0.01% if the gas is to be discharged into the work room.

Dilution of the flue gases to a concentration of 0.01% CO would require the addition of
$(465 \times 0.01 - 465 \times 0.0001) \div 0.0001 = 46{,}040$ cu.ft. of air per min.

Add 465 cu.ft. to this, as representing the volume of the original products of combustion after cooling to 90° F., and the volume of gases containing 0.01% CO is $46{,}040 + 465 = 46{,}505$ cu.ft.

The lead concentration in the diluted gas would be
$(416 \times 10) \div (46{,}505 \times 0.0283) = 3.15$ mg. lead in 10 cu.m.

This concentration is very near the threshold value, indicating that the hazard from carbon monoxide and the hazard from lead are of about the same magnitude. Since excessive carbon monoxide produces symptoms very rapidly (headache and dizziness) there is little danger from having an unknown lead hazard.

Such calculations as the above will not apply to electric or muffle heating furnaces. With furnaces of these types the rate of lead release must be compared directly with the ventilation surrounding the furnace.

released. This amount of scale is dependent upon the size of tip used; the larger the tip, the more rapid the welding and consequently the less heating and scaling near the weld. Because of these variables it is impossible to give exact figures for the rate of lead release during gas welding. However, since gas welding is slower than arc welding the total rate of lead release is less. A close approximation is half the rate.

Remelting Scrap—If Ledloy scrap is remelted under oxidizing conditions, all of the lead will go into the atmosphere. In openhearth furnaces, cupolas or other types of furnaces in which the gases pass out into the open air, calculations will show that there is no possibility of developing a hazard. If the scrap is charged to an electric furnace without an exhaust system the amount of lead-bearing scrap charged must be limited so that the ventilation surrounding the furnace will keep the lead concentration below the threshold value. The calculations for this contingency are exactly the same as those for other operations except that *all* of the lead in the metal must be considered.

Conclusion

Research on Ledloy steels has shown that no lead is given off by the solid steel, even though heated. The 0.25% lead is dispersed throughout the metal in small particles and since lead is insoluble in iron it cannot migrate to the surface. If the steel is turned to scale or melted, the lead in the metal so altered becomes available and a certain proportion of it passes into the air. The proportion of lead released under various conditions has been determined, so that simple engineering calculations will show whether a hazard can develop under any particular circumstances. The amount of lead given off at any but the highest temperatures is so small that no calculations are necessary. The investigation indicates that there is no health hazard in handling, machining, heat treating or in ordinary forging of Ledloy steels. When, however, such steels are to be welded or flame cut, calculations should be made to determine whether or not lead concentrations above the threshold value will develop. If it is found that the operation will result in a lead concentration above the threshold value, an exhaust system should be provided. In practically all cases the amount of air to be moved for satisfactory exhausting is small, and inexpensive equipment will be effective.

GAS ENGINE VALVES

By S. D. Heron, O. E. Harder and M. R. Nestor

Extracts from "Exhaust Valve Materials for Internal Combustion Engines", a paper for the A.S.T.M. Regional Meeting, Detroit, March 1940

IN A four-year development of a new valve steel, the available laboratory tests have been scrutinized and found insufficient to evaluate correctly the steels much used at present. In the new research several tons of steel were procured, several changes in analysis made to improve forgeability and machinability, over 1000 experimental valves were made, leading up to more than 10,000 hr. of engine testing on the dynamometer, and over a million miles on the road. This extensive program was necessary despite the fact that the steel type under investigation showed outstanding results in its first engine test.

Among the many destructive agencies acting on a valve in service, corrosion by hot exhaust gases may be mentioned first. Of these the most important are lead compounds, oxygen, and reducing agents such as partially burned hydrocarbons, carbon monoxide and elemental carbon. The best laboratory tests to evaluate the resistance to such actions are *(a)* weight loss after a short immersion in molten lead compounds and *(b)* loss after cyclic heating and coolings in the gaseous combustion products.

Cold corrosion by moisture condensed from exhaust gases is likely to cause much trouble from stem sticking. Service experience can be duplicated by observing samples after being sprayed daily with engine exhaust condensate.

Many mechanical properties are important; their relative standing is doubtful, but one of the most necessary is "hot hardness". This is related to resistance to battering or upsetting at the seats, and to scuffing at the guides. Unfortunately, also, the maximum hot hardness means poor forgeability (or even non-forgeability, as in Stellite). In the laboratory the preferred test is that of mutual indentation of a pair of short cylinders pressed together, while hot, along a common element of their surfaces. Operating (and test) temperatures are 1800 to 1900° F., and this is so far above the critical range of carbon and low alloy steels that any hardness *(Cont. on page 456)*

BOOK REVIEWS

An Elementary Text

MODERN STEELS, MANUFACTURE, INSPECTION, TREATMENT AND USES, a series of lectures by Max W. Lightner, G. R. Fitterer, Ernest E. Thum, Franklin H. Allison, Jr., A. W. Demmler, and James P. Gill. 371 pages, 6x9 in., 147 figures. American Society for Metals, Cleveland. Price $3.50.

Reviewed by A. Allan Bates

When, in 1937, the Pittsburgh Chapter of the ⊜ decided to present a course of educational lectures covering the present day metallurgy of steel, it chose five of its eminent members to share in the task. This book is the written version of the resulting 13-lecture series. With the unsurpassed Pittsburgh field of talent from which to draw, it follows naturally that the volume is competently authored.

It is the reviewer's inclination to stop at this point — for any thoughtful reader even slightly familiar with the subject will realize that the above information, "375 pages . . . . competently authored", constitutes a complete and favorable review. But the reviewer knows that Editor THUM has set aside more space than that will fill; hence the remaining relatively inconsequential remarks which the truly interested reader may as well skip.

Beginning on page 1 with "Raw Materials" the book sweeps rapidly through an account of the blast furnace, steel-making, the rolling and finishing departments and brings the reader, as though by appointment at page 100, to "Inspection and Testing". This first section constitutes a presentation of production metallurgy and has been successfully streamlined only by resolute determination on the part of the authors to stick to main facts and let the details appear, by implication, between the lines. No chemical equations have been used but an abundance of excellent illustrations is provided. A high school course in chemistry will be a convenient but by no means necessary preparation on the part of the reader.

On page 101 "Modern Steels" plunges into physical metallurgy and, again in swift moving language aided by plenty of diagrams and illustrations, covers the subject in exactly 100 pages. In this section inspection and testing, crystallinity, thermal analysis, allotropy, equilibrium diagrams, transformation rates, typical microstructures, are briefly but clearly treated in terms which require no great scientific preparation of the reader.

The third section on treatment, selection and uses of steels starts out with a metaphorically couched warning by author, A. W. DEMMLER, that one doesn't "learn to play the piano in five lessons" — an excellent bit of wisdom which should have been enshrined on page 1. The chapters on treatment are eminently practical and include descriptions of equipment and of common shop procedures such as hardening, annealing, normalizing, carburizing and nitriding. At the same time such topics as the effects of mass, grain size and composition, and of thermally induced volume changes are given due discussion.

The final portion of the book comprises, in addition to a chapter on "stainless steels", two other chapters, one of 28 pages on all the S.A.E. steels and one of 36 pages on toolsteels, all very good. However, this division of attention is entirely unjust to the S.A.E. group and constitutes the reviewer's principal criticism. Within the limits of time and space allotted him author JAMES GILL has done a fine job — it would be difficult to pack much more broadly useful information into 28 pages. But it would have been decidedly better had he been allowed two chapters for the job.

Being a Westinghouse man and of naturally churlish disposition the reviewer will quibble over a statement made on page 297, "In 1934 HULL and BURGER of General Electric's research laboratory developed . . . . 'fernico' containing 28% nickel, 18% cobalt and 54% iron . . . .". This alloy was developed by HOWARD SCOTT at the Westinghouse

research laboratories and described by him in 1930 in the *Transactions* of the Institute of Metals of the A.I.M.E. It is patented and manufactured by Westinghouse under the trade name "Kovar".

In summary "Modern Steels" is to be recommended as an excellently readable, entirely authoritative, condensed review of the present day metallurgy of steel, wherein the technical and scientific aspects of the subject are presented capably but not in a manner formidable to those who lack scientific training. There are many who will find it a most useful book.

Essay on Fatigue

FATIGUE OF METALS *(La Fatigue des Metaux)*, by R. Cazaud and L. Persoz. 190 pages, 6¼x 9¾ in., 121 illustrations. Dunod, Paris.

Reviewed by H. F. Moore

In the field of materials of construction, changes in practice and new developments in accepted theory have taken place very rapidly during the past 30 years. This is strikingly illustrated by the constantly changing picture of the phenomenon of progressive fracture under repeated stress, commonly called fatigue of metals, a picture presented in this book by CAZAUD and PERSOZ, which gives a careful summary of the knowledge up to 1937. This, so far as the reviewer is aware, is several years later than the period covered by any other general book on the subject.

The opening chapter is a historical summary, with citation of several early studies not given in most other books on the subject. This is followed by chapters on the characteristics of fatigue fractures, on the mechanism and theories of fatigue failure, on fatigue testing machines and specimens, a summary of results of fatigue tests from many laboratories, a chapter on the influence of effects of various factors including speed of testing, overstressing and understressing, periods of rest, stress-raisers and stress concentration, surface conditions, internal stress, temperature and corrosion fatigue. A brief discussion is included of tests of riveted, soldered and brazed joints.

This book is recommended to those students of materials who can read French, or who wish to "brush up" on their French. It is written in the clear style characteristic of good French scientific writing. Extensive references are given to the work of metallurgists and testing engineers in many countries.

General Metallurgy

METALS, by Sir Harold Carpenter and J. M. Robertson. Two volumes; 1485 pages, 6¼x 9⅝ in.; 577 figures. Oxford University Press, New York. $35 (£5 5s in England).

Reviewed by Ernest E. Thum

This work is too important to argue about the price differential charged Americans.

Advance in the science of physical metallurgy may be judged by comparing this book with several much-used predecessors. DESCH's "Metallography" (1910) had little besides equilibrium diagrams and metallographical technique. ROSENHAIN's "Physical Metallurgy" (1914) paid the first real attention to the properties of metals as related to their microstructure. SAUVEUR's "Metallography and Heat Treatment of Iron and Steel" (1915) was descriptive rather than philosophical, and confined to one family of alloys. In HOYT's "Metallography" (1920) the emphasis on laboratory technique was suppressed in a small first volume, and a larger second volume presented facts about the properties and structure of the commercial alloy systems. By 1924 some systematization of the volume of isolated data became possible and JEFFRIES and ARCHER's "Science of Metals" appeared, with its important generalizations on grain growth and on hardening processes. During the next 15 years a mass of literature and a number of books appeared about new investigational techniques, and the properties and structure of individual metals and their alloys.

Now (1939) come these two volumes on "Metals" by members of the metallurgical faculty at Royal School of Mines in London. They contain little or nothing about experimental technique but a very complete statement of metallurgical theory, each proposition illustrated by examples from the alloys of the principal common metals. The manner of treatment, wherein the evidence is set forth briefly and the underlying theories or hypotheses stated, expounded and criticized, is strongly reminiscent of the literary method used by HENRY MARION HOWE in his classic "Metallography of Steel and Cast Iron" (1916). HOWE was responsible for much of the data in his own book; the same is true of the books "Metals" under review — especially in the first part of Volume II where the structure of steels is described.

"Metals" starts off with no definition of "metal". Probably the entire work, 750,000

words, is necessary to define the word, and that even incompletely. Only seven of the 72 metallic elements are systematically studied, although innumerable facts about others are brought in to support some principle or to dispute some hypothesis. These seven are the important ones — iron, nickel, copper, aluminum, zinc, lead, and tin. Likewise they must be fairly representative of the 34 commercially useful ones; for instance, we are now attempting to explain things on the basis of atomic structure and arrangements and these seven metals crystallize in five of the common space lattices, and contain representatives of four of the six groups of valency electrons attached to metals.

This atomistic viewpoint, the realization that *time* is an essential in all physical and chemical reactions even in metals, and that concentration gradients are the normal conditions in alloys, are responsible for the main differences between this book and its predecessors. The old ones were mainly concerned with equilibrium conditions; the new one realizes that these are seldom if ever achieved — in fact, most of the important metallurgical practices make use of interrupted reactions or are vain attempts to approach equilibrium. It is essential to take account of chemical dynamics in order to have an understanding and control of annealing, hardening, creep, fatigue.

Notable discussions in this work include one on the hypothesis that amorphous metal cements the crystalline grains together, is formed by plastic deformation and is responsible for the observed strengthening by cold work. This hypothesis the authors reject, even though they agree with BEILBY's original proposition that the polished surface of metal is a highly disorganized layer which, if crystalline at all, contains crystals too small for our present powers of identification. Measures of the up-to-dateness of the book are an adequate discussion of grain size control in the steel mill and its implications in customers' plants (a matter well understood and practiced in America ten years before it was put into commercial use in Great Britain), a review of the latest work on the mysterious happenings in alloys during the very early stages or incubation of precipitation hardening, a discussion of the mechanism whereby fatigue cracks start, and the "order-disorder" relationships in the quasi-transformation in β brass.

Considerable interest also centers in CARPENTER and ROBERTSON's description of the hardening reactions in *(Continued on page 448)*

New Techniques

THE PHYSICAL EXAMINATION OF METALS; Volume I — Optical Methods, by Bruce Chalmers. 180 pages, 5½x8½ in., 97 figures. Longmans, Green & Co., New York. Price $4.

This well-printed British book (it is really published by Edward Arnold & Co. in London) is a comfortable little one to handle. Written by the distinguished physicist of the International Tin Research & Development Council, it outlines the latest adaptations of interferometers and polarized light to metallurgical work, and is therefore a timely exposition of principles, equipment and methods. It is another exemplification of the fact that a true expert can describe his specialty in understandable language. Most of the literature references date from the last five years, and this is evidence of the increasing reliance of metallurgists upon the tools of advanced physical research.

Some applications of optics are so well established that Dr. CHALMERS gives them hardly more than mention, such as microscopy and pyrometry — even spectrographic analysis. These subjects require extensive treatment in themselves. He therefore confines his attention primarily to experiments on the surface condition of metals — smoothness, oxide layers, adsorbed gas films, passivity — by the measurement of reflectivity, interference fringes, diffraction phenomena and polarization of reflected light. One gathers that the interpretation of tests so far made is not always clear; the optical experiments probably are only a jump or two ahead of work with electron diffraction apparatus. Doubtless a better view of surface conditions will come from the combined use of optics and electronics.

Lest the matters discussed so clearly in this book be dismissed by the practitioner, he should know that the interferometer is the main reliance of those who must check gages to fractions of thousandths. Extensometers using interference fringes are so accurate that temperature must be held rigorously constant, else thermal expansion of the test piece will vitiate the observations. Diffraction of light is used, not only in the gratings of spectroscopes, but also in determining the resolving power of microscopes, the mesh of fine screens, and has some possibilities in measuring grain size of metallic powders. Much recent work has been done with

polarized light for ordinary micro-examination; it enhances contrasts and is especially valuable for the identification of slag inclusions and carbides. Dr. Chalmers gives tables of the properties of structural constituents which will be useful in the latter service.

Lathe Speeds and Feeds

Manual on Cutting of Metals *With Single Point Lathe Tools*, prepared by the A.S.M.E. Committee on Metal Cutting Data. 319 pages, 5½x8½ in., limp binding, round corners. The American Society of Mechanical Engineers, New York. Price $5.

The formula for computing safe loads on a beam is a simple equation involving four factors, two of which are taken from a table of constants for the chosen shape, and the result is read from a single setting on a slide rule. Even so, structural handbooks contain extensive tables showing safe loads on various beams of different spans — and presumably they are much used by designers.

Contrast this painless extraction of design data with the difficulties faced by the engineer who wishes to estimate economical cutting speeds on a modern lathe. His equation, more or less empirical, involves about ten variables (some with fractional exponents) including such things as depth of cut, feed, tool shape, desired life and metal being cut. How much more necessary is it for him to have tables, worked out in advance, from which he can select the optimum values! Yet it has taken some seven years' work on the part of the A.S.M.E. committee to assemble existing data, supply missing items by original research, and reduce the mass into manageable shape. This present result is a manual that should be of inestimable value to estimators, foremen, production supervisors, mechanical engineers, and metallurgists who have anything to do with tool room problems.

Core of the book is 245 tables covering the machining of 35 commonly used S.A.E. steels by seven differently shaped tools (four roughing, one finishing, one parting and one forming tool), all made of standard 18-4-1 high speed steel. Every table for roughing, for instance, contains both the cutting speed (tool life of 60 min., working dry) and the horsepower required, for seven feeds varying from 0.002 to ⅛ in., each for nine depths varying from $\frac{1}{32}$ to 1 in. Supplementary tables and illustrative examples show how to modify the results for the use of coolants, for some other life of tool, for some other hardness of the steel, and for other varieties of toolsteels and tool materials. While these 35 steels are the ones most commonly machined, an extensive table permits one to derive values for a more complete list of 289 steels and conditions. For good measure the book contains enough data to enable one to compute, with a less degree of accuracy, similar information about the turning of 27 cast irons and 31 non-ferrous metals.

Welding Practice in 1938

Arc Welding in Design, Manufacture and Construction. 109 of the papers awarded prizes by the James F. Lincoln Arc Welding Foundation. 1410 pages, 5½x8½ in., 695 illustrations. Published by the James F. Lincoln Arc Welding Foundation, Cleveland. Price $1.50 in U.S.A.; $2 elsewhere.

Book reviews are published in Metal Progress at such rare intervals that a second edition of the book may be on the press before the notice appears in these pages to remind tardy purchasers they have missed a good buy. This is almost a case in point. The book whose title appears above (published in March 1939) is the result of a notable Lincoln prize competition; even now the second $200,000 Industrial Progress Award Program is organized by the same Foundation and under way.

It may be recalled that the former competition was designed to distribute major awards to 220 authors, writing about economies effected by arc welding in 11 industries. In addition there were 178 minor money awards and honorable mentions. These awards were so rich (compare Lincoln's $200,000 with the movie industry's national $250,000 competition last summer) that a large room was necessary to store the 1980 papers submitted by engineers from all over the world. It was a staggering job to read and grade them for awards, but this was summertime work for a jury of 30 college professors. Even more difficult it was to edit the cream of the award papers, 109 of them, into such length that they could be printed in this 1400-page book, work done most creditably by E. C. Powers, assistant secretary of the Foundation.

It is very obvious, from the source of these papers, that this book is the unique and compre-

hensive record of the art and practice of electric welding, as it existed in industrial America in the late 1930's. Much, even, of foreign practice is included. Anyone who does any welding or supervises it, or contemplates its desirability, should consult this book. The chances are it will tell him how someone else has solved the same problem he is working on; the certainty is that it will stimulate his thinking along all phases of metallic manufacture.

A Book of Data

METALL-TECHNISCHES TASCHENBUCH, by William Guertler. 370 pages, 6x8¼ in., 445 illustrations. Johann A. Barth, Leipzig, 1939. Price 50 reichsmarks.

Reviewed by Erich Fetz

This metallurgical "pocket-book" represents an extensive compilation and critical evaluation of technical and scientific data scattered in the international literature, and pertains to composition, structure, utilization, chemical, physical and mechano-technological properties of metals and alloys, to their treatment, working and testing.

Although aided by a good many tables, preference is given to presentation by curves instead of by numerical data. That is the principal reason why this book can be recommended to those American metallurgists who have no command of the German language. Only about 30% of the space is devoted to the text and 70% to illustrations and easily digestible tables. By using the millimeter scale throughout the book, fairly accurate values may be taken from the diagrams. Practically all binary constitutional diagrams (Why an antediluvian Cu-Sn diagram?) are wholly reproduced or sketched. Special features are the great number of ternary diagrams and GUERTLER's efforts to point out the possibilities of developing new alloys. Naturally, German endeavors to find substitutes for Ni, Cr, W, Pt, Sn and Hg in new commercial *Ersatz* alloys play a certain role in the otherwise unbiased book.

The designation "pocket-book" should not be taken literally, as it hardly fits into any pocket. Without detracting from the value of the book, it must be said that the paper is decidedly poor *(Ersatz?)* and that print and illustrations are rather small. Obviously, it had been the intention of the author to cramp as much knowledge into his book as possible. It may be justly called "International Critical Tables" in miniature. With the emphasis on the wealth of numerical data, the new GUERTLER represents a reference book equally valuable for scientists and plant engineers.

Another Elementary Text

THE ELEMENTS OF FERROUS METALLURGY, by Joseph L. Rosenholtz and Joseph F. Oesterle. Second Edition, 250 pages, 9x12 in., 140 illustrations. Published by John Wiley and Sons; price $3.

When one picks up a book whose scope is the mining and smelting of iron ore, the refining and rolling of steel, its constitution, heat treatment and uses, and foundry practice as well, and finds that the text is compressed to 65,000 words (about equal to two issues of METAL PROGRESS), he is sure that the word "elements" in the title is well chosen. Evidently the book is intended for civil, electrical, mechanical and other engineering students, rather than for metallurgists. For these men the emphasis should be on properties, treatments and uses rather than production methods; such being the plan of the book, it would appear that the 20-odd pages devoted to wrought iron and crucible steel could have been used otherwise to better advantage. Only a simplified treatment of the chemical processes of iron reduction and refining is presented; this is in keeping with the scope of the book and its anticipated student use, but the reviewer could only wish that the reality were so simple, so straightforward and so non-reversible!

The illustrations are well chosen and represent modern practice, except that a 20-ton open-hearth is illustrated — maybe a zero was left off the caption. A strange lapse, also, is the failure to mention and illustrate continuous sheet mills and the modern production of steel sheet.

The authors are praiseworthy in using the "S-curve" of DAVENPORT and BAIN to explain the transformation of austenite on quenching, and the nature of the micrographic constituents. Now and then the text is old fashioned, however. As an instance it gives two double-treatments for the hardening of carburized parts (which may still be done somewhere) but makes no mention of the very common quench direct from the pot. E.E.T.

A MAN OF METALS

The New York Times Studios

Walther Mathesius

From a long line of German teachers, ministers and engineers, he came to America in 1911 and during the next 20 years at South Chicago became known as a most skillful blast furnace operator and steel mill executive. He is now vice-president in charge of operations, U. S. Steel Corp.

Metal Progress; Page 424

WALTHER MATHESIUS has made a very special place for himself in American industry. Beginning as a technical blast furnace operator, he has become a fine executive with a broad view of his industry and the energy to put his wealth of knowledge to effective use, at the same time being a leader alert to his many responsibilities. Coupled with this forcefulness in his work is a personality that has warmth and kindliness, and a genuine desire to be helpful to his associates.

In reviewing his industrial activities, it may be said that WALTHER MATHESIUS has carved two niches for himself, the later growing out of the earlier. His earlier phase was devoted to the iron blast furnace, and was characterized by his success in applying scientific inquiry to the workings of the furnace. As industrial operator, he used his scientific training to combine science with the requirements of practice, and became widely known as an authority in his field. But in this period he was also acquiring that broader outlook in the steel industry which led to his rapid advancement in steel operations on a broad scale. His present position in industry is well known to men in the steel trade: Vice President, Operations, United States Steel Corp. of Delaware, to which post he was appointed in 1938.

His metallurgical history really started long before his own career began. In so young a science as metallurgy, it is odd to think of a metallurgical dynasty, but the Mathesian Metallurgy began over 350 years ago! In 1587 in Nüremberg there was printed the "Bergpostilla" by JOHANN MATHESIUS, a technically informed minister who (according to a history of the period) "delivered each year a sermon on metallurgy, in which, combining technology and theology, he led the thoughts of his mining flock from their daily work to contemplations of eternity". The Bergpostilla (whose cover is photographed on the next page) is a collection of these discourses, on gold, silver, bronze and of course iron and steel. Although WALTHER, at the present day, contemplates these beginnings with mixed feelings (including consternation), the family records from then on show a series of teachers, ministers and engineers, leading to WALTHER'S father, also a WALTHER MATHESIUS, professor of metallurgy at the Institute of Technology, Berlin.

After completing his formal training with a doctor's degree at the Institute of Technology, Berlin, in 1911, "young WALTHER" came to the American Steel and Wire Co., Worcester, Mass., remaining one year before moving to the South Works (Chicago) of the then Illinois Steel Co. The South Works, and the Chicago district in general, was the proving-ground where, over a period of about 25 years, he vigorously and tenaciously crusaded for his way of thinking in the industry. His work very early caused him to be made assistant superintendent of blast furnaces, subsequently becoming superintendent, then assistant general superintendent of South Works and then general superintendent. Upon formation of the Carnegie-Illinois Steel Corp. in 1935, he was made manager of operations of the Chicago district, a position he held until appointed to his present post.

MATHESIUS is the author of numerous technical papers, especially on the blast furnace process and its construction and operation. Of particular importance are three papers, "High Blast Heats in Mesaba Practice" read before the American Institute of Mining Engineers in 1915, "Chemical Reactions of Iron Smelting" and "The Blast Furnace Hearth", before the American Iron and Steel Institute in 1917 and 1920 respectively. These papers of 20 years ago are quoted today as standard in fundamental discussions of this subject.

In his own modest estimation, his favorite published works are those which discuss the fundamental researches which led to certain theoretical conclusions; but he admits that subsequent papers, describing the application of these theories in practice, had a more immediate and widespread effect in industry. As to technical viewpoints, it seems not improper to quote from one of his own recent articles:

"I should like to pause and look back 20 years or more to the time when members of the ancient and honorable blast furnace guild matched their inherited wisdom, skill and tenacity against the proverbial fickleness and cruelty of their charges. Special notices were posted (some still existing) bidding all and sundry to stay away and granting access only to the crews, the *morituri* of the industry. And these warnings were no nursery-tales, as we know who lived through weeks and years of high blast pressure, hanging periods, slips, explosions and breakouts . . . But . . . we pursued our search for the real causes of our troubles. We adapted facilities and practices to the changed

nature of our raw materials, the soft, fine Mesaba ores and the smaller, more open-structured, more friable by-product coke. We learned to grade our materials for constant physical and chemical properties, we redesigned and strengthened our equipment, to provide additional security and smooth, uninterrupted performance. In short, we adopted the tactics of the Chinese doctor, who, we are told, was paid to keep his patients well and who forfeited his fee when he failed to do so."

For the economic attitude concerning steel making we may quote: "From a practical and economic viewpoint, steel quality is that group of properties essential to the constant production of finished goods of merit, measured in terms of satisfactory service rendered at the lowest ultimate cost. In this sense it is an ever changing and competitive standard." For his concept of the administrator, one learns from his daily acts that he is a modern, forward-looking executive, conscious of the responsibilities for administration of an active enterprise, keenly aware of the problems of the individual, and always alert to conserve human values.

His achievements and his popularity are results of an outstandingly well-rounded personality. One thinks of WALTHER MATHESIUS not primarily as an intellect that has produced hard facts, nor merely as one so well versed in the many technical and human aspects of the steel industry that he has become recognized as a real executive, nor solely as a man with vision who sees his industry in its correct perspective in a technical age, nor even primarily as a personality with such kindliness and insight that one always feels at home with him. Rather does the mention of WALTHER's name bring *all* of these qualities to mind almost simultaneously. If you ask him for an opinion, he will quite invariably say "Well, let's sit down and analyze the situation"; he is not content merely to express an opinion — he wants the other person to understand the point of view which leads to the opinion. And one is aware of a breadth of knowledge and a freedom from bias so unusual as to mark him out in any group. This distinction comes from nothing ostentatious; rather, over a period of time there grows on one the conviction that here is solid worth.

He is a member of numerous technical societies, and in the American Society for Metals has found time to act as a trustee of the National Society.

Physically, one finds a man of large stature, a head proportioned to broad shoulders, a large frame and impressive hands. This considerable person greets one with friendliness and sincerity, as his host of friends and associates are happy to attest. He has been most fortunate in his family life. His wife (born EBBA W. J. AF EKSTROEM) is a charming woman and a talented musician. They have two sons, WALTHER and HERMAN.

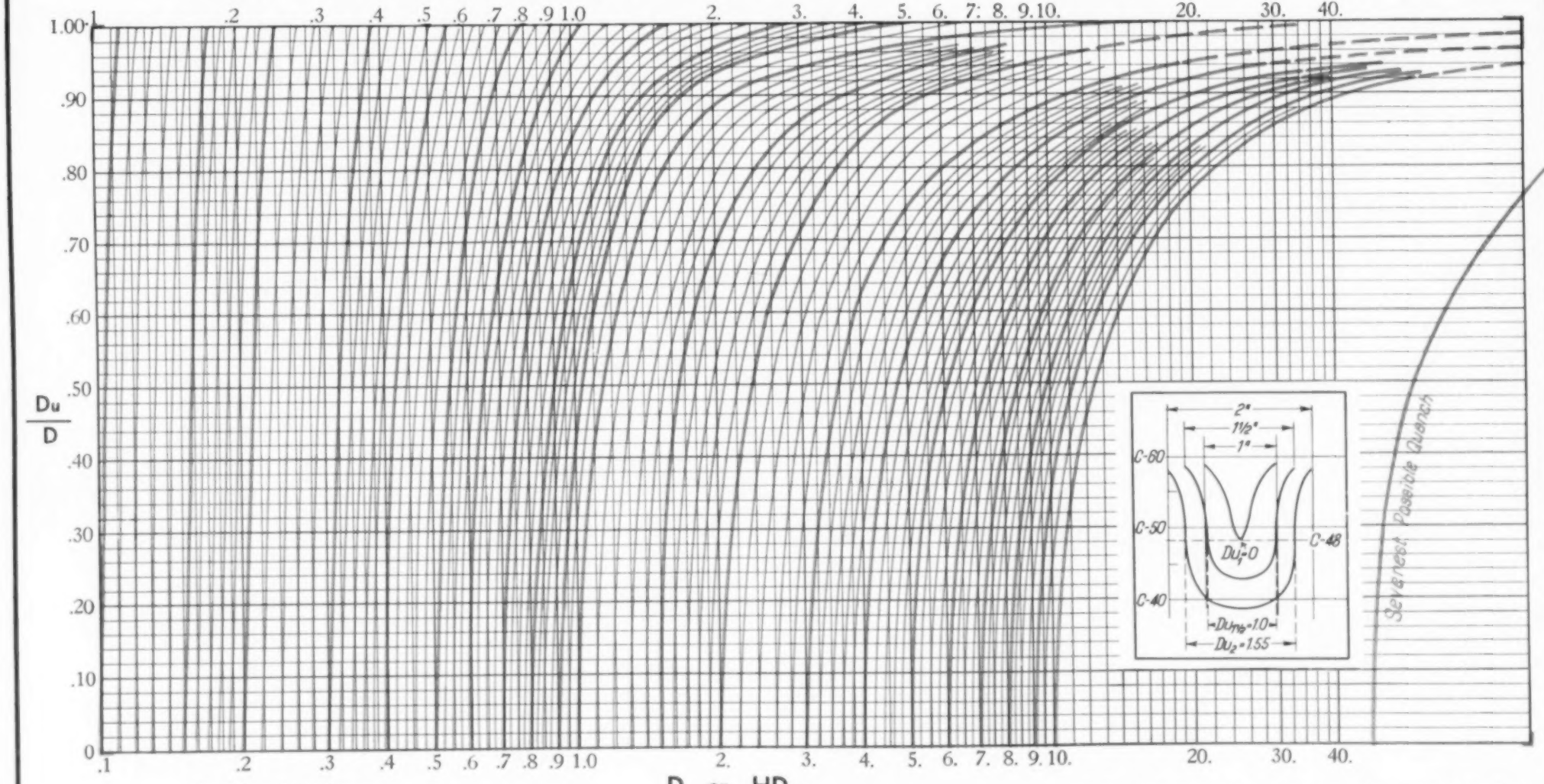
Our hero mentions music and outdoor activities as his hobbies, but (confidentially) he doesn't have too much time for the enjoyment of them.

Three Examples of Mathesian Metallurgy, 1587, 1886 and 1935

METAL PROGRESS APRIL, 1940; PAGE 427

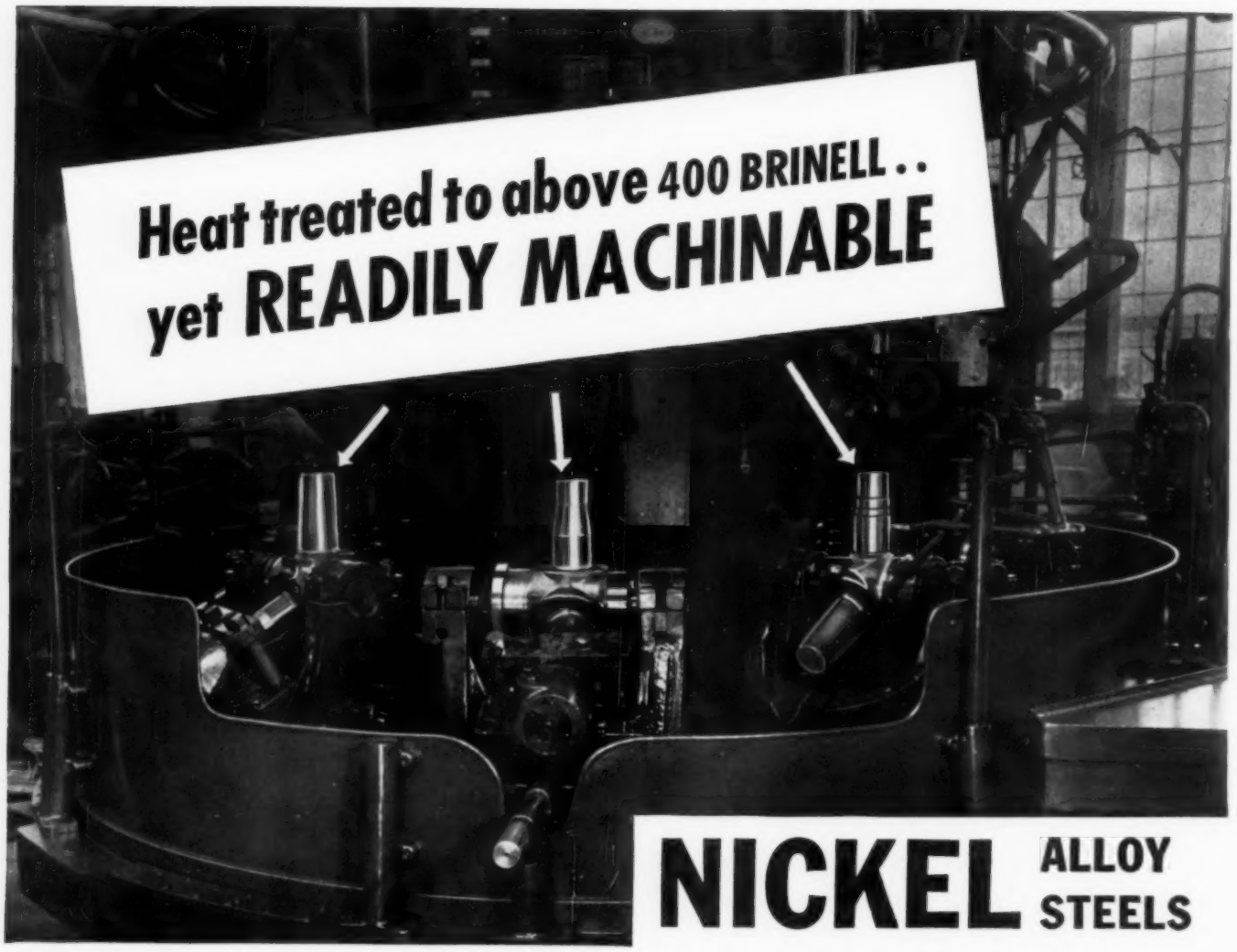
Cooling Power of Quenching Baths

Curves whereby severity of quench (heat transfer equivalent H) can be estimated. Copyright, 1939, Carnegie-Illinois Steel Corp.



By Morris Asimow and Marcus A. Grossmann

TO USE this chart, harden at least three bars of various diameters in the given medium at working temperature and circulation, and determine curves of hardness distribution, edge to axis, at mid-length. In the example sketched in the inset above, D is 1, 1.5 and 2 in. respectively. At a selected hardness horizontal, as C-48, which intersects or touches all curves, determine the ratio $Du \div D$ between soft center and bar diameter. (Soft center diameter Du is 0, 1.0 and 1.55 in.; $Du \div D$ is 0, 0.66 and 0.77 respectively.) Lay a piece of tissue paper over the chart with its edge at the base line and plot $Du \div D$ against D for each bar size. Slide tissue paper right or left until these points fall on a single curve, which for this quench happens when D_1 is at 5.0 and $D_{1.5}$ is at 7.5 (these now being values of HD). Then H, the severity of this quenching set-up, is $HD \div D$ or $5.0 \div 1.0$ or 5.0 (or $7.5 \div 1.5$ which gives the same result).



NICKEL ALLOY STEELS

For parts subject to high stresses in service, heat treatment *before* machining offers many advantages. Warpage and distortion frequently resulting from heat treatment after machining are minimized. In addition, points of stress concentration are avoided resulting in considerably greater life for the machined part when placed in service.

Especially interesting are present shop practices of airplane part and other mass production plants now machining heat treated Nickel alloy steels ranging in hardness up to 450 Brinell. *(above)* Stressed Hydromatic Propeller spiders of SAE 4340 heat treated to approximately 415 Brinell are machined with ease in the regular production line at the East Hartford, Conn. plant of Hamilton Standard Propellers, Division of United Aircraft Corp.

• • •

In a recent demonstration on a standard Warner & Swasey turret lathe conventional high speed tools readily turned, chamfered and drilled a 2″ bar of Nickel-chromium-molybdenum steel at a hardness of 450 Brinell. The turning cut was fed at .012″ at a speed of 42′ a minute. The close helical chip showed no tendency to tear, check or burn. The smooth surface produced indicates that machining Nickel alloy steels at high hardness is not unusually difficult.

Hamilton Standard Propellers, Division of United Aircraft Corp., East Hartford, Conn. regularly machine SAE 4340 stressed Hydromatic Propeller parts including spiders, illustrated here, and cams after they have been heat treated to approximately 415 Brinell. Hard Nickel alloy steels are no hazard where machining is concerned. For additional information please write to the address printed below:

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK, N. Y.

CRITICAL POINTS

by the editor

SLIPPED, SLID, and slithered in VERYL GRAZE's car over 50 miles of icy roads to Canton and Massillon, to be at Republic Steel Corp.'s inauguration of an enlarged plant for making about 1000 tons a month of stainless steel strip. Much impressed by the change that has come about in a half-dozen years; *then* a little cold-rolled strip was made occasionally along with much more of wide, long sheet, delivered after giving it a high polish; *now* the strip tonnage has so grown that the new finishing department looks like a small edition of one of the recently built continuous sheet mills, and the product is mostly shipped with cold-rolled finish. Coarse crystalline ingots and "inherent brittleness" of 16 to 18% chromium steel seem to have lost their terrors, for these alloys are given reductions on schedules little less severe than carbon steel would get. VIRGIL WHITMER, metallurgist in Republic's Central Alloy District, explained the process annealing in detail, for the methods and equipment are far different from their counterparts in a sheet mill. No less than five continuous lines are available for re-softening cold-rolled strip. Heating is more of a normalize than an anneal; the strip is suspended through the furnace, free of any support, being pulled through against hold-back pads. The furnace therefore is short; quick heating is by open flames above and below. An oxidizing atmosphere puts a smooth, thin, bronze-like scale on the strip, free from that greenish color that is almost impossible to remove. Pickling is in either sulphuric acid or nitric acid solution; each line has two short tanks, and here again the sheet is free of solid contact except from hold-down rolls at entrance and exit. En route the strip passes between six pairs of flat bar electrodes. Current from a plating generator is led into top and bottom surface of the strip from the first three pairs, thus plating out hydrogen and accelerating the decomposition of the scale; current exits from the strip to the second three electrode pairs, thus "electrolytically polishing" the surface to a small extent by carrying off metal ions from protruberances. A balance may be struck between the "frostiness" of the emerging strip and its softness (a more thorough, longer heating involves a deeper scaling) and the subsequent amount of cold work. For a satisfactory surface after a final pinch pass, the frostiness is held at a minimum.

stainless strip in tonnage

TO ECORSE with CHARLES LAUFLE, manager of alloy division of Great Lakes Steel Corp., and happy to find LUCIAN SELMI still active in the business, remembering that 25 years ago he was about the only metallurgist ("chemist" in those days) who was willing to speak out in public about the mysteries of soft steel sheet. CLARENCE ALTENBURGER showed me his bustling research department, and outlined its studies on non-aging steel for deep drawing stock, from which an interesting development has been a high strength steel called "Ductiloy" that was formulated to be much stronger than low carbon steel sheet yet approach its superior drawing qualities, have no banding in the microstructure, be non-aging, weldable, have high impact and fatigue resistance even at sub-zero temperatures, and be sold at a price in competition with high elastic limit steels made by other steel producers. Truly, a formidable list of requirements! Carbon is kept below 0.15%; high yield strength is given by 0.80% silicon, 0.60% chromium and 0.15% nickel. The two latter plus 0.25% copper lend good resistance to atmospheric corrosion. Zirconium (0.10 to 0.15%) is relied upon to fix the oxygen and nitrogen, give a fine grain size and a high coarsening temperature. From the commercial side, success has been achieved in such things as replacing S.A.E. 1020 steel stampings in motor truck and bus underframes and wheel centers, thus increasing their

cold forming strong steel of unusual ductility

safe capacity without any change in design or dies. More interesting possibilities lie in the field of cold forming, where coined pieces large and small of superior dimensional accuracy can be made, usually without any intermediate anneals, and possessing high strength (due to the cold working) equivalent to that of heat treated medium carbon steel forgings.

TO SOUTH BEND, home of Studebaker, Notre Dame, and Bendix, and at the University ED. MAHIN showed me about one of the most compact, best organized and equipped metallurgical departments I have ever seen. ALEXANDER TROIANO, his associate professor, was as proud of a new X-ray diffraction laboratory as a new papa, and impatient to get it working on some puzzling intermediate transformations in iron-alloy systems. Talked to the ⚙ Chapter about the ultimate cause of cohesion and hardness — a matter of no practical importance whatever. (To prove this, look through BAIN's very useful and practical "Functions of the Alloying Elements in Steel", and you will find things explained in terms of the microstructure of plain carbon steel; the nearest to first causes he finds it necessary to come is to state that the finer the dispersion of hard carbide particles in a soft iron matrix, the greater the hardness of the aggregate.) Lest some casual reader may worry about this, the conclusion is that "Why is an electron attracted to the nucleus?" is a meaningless question to us in our present incarnation and with our present experimental techniques. Later, when we reach a new frame of reference, we may have some chance to approach an understanding.

electronic stick-um

MARVELED at the empirical nature of some tests, when JOE FOX, chief metallurgist for Doehler Die Casting Co., said that a much-used test for cooking utensils concerned the degree of blackening after boiling one egg for five minutes. (Eggs, presumably, must pass the candler; disposal of the used materials might also be a problem in a busy laboratory.) Evidently the water increases slightly in alkalinity from the egg shell, and this promotes corrosion of the aluminum. The most resistant alloys get an oxide film of exactly the wrong thickness — it gives a black interference color, if that term is admissible. Perhaps a more scientific statement is that the metal surface, underneath the translucent oxide layer, is so intensely and minutely roughened that it absorbs nearly all of the incident light. The cure, from a housewife's standpoint, is a *more* corrodible alloy which will be *more* and coarsely roughened, and so reflect some diffused light. Another point: Some of the copper-bearing alloys formerly used had a tendency to develop a single deep pit. To insure against this the interior of the utensil was given a wire-brush finish — so many small scratches which induced such a multitude of small pits that the result was about the same as general over-all corrosion at a very slow rate.

discoloration of aluminum utensils

MUCH PUZZLED by the fact that a dozen or more processes are in use for the production of metal powders, a list doubtless containing some evanescent methods despite their present adaptability to the metal and the raw material now available. Several are in operation at Metals Disintegrating Co. at Elizabeth, N. J., an interesting plant inspected under the guidance of HAROLD HALL, its energetic young manager. Molten tin, lead, aluminum and copper are atomized in air-conditioned rooms (excess humidity balls-up the powder) and caught in cyclone dust catchers and bag houses. Such aluminum powder is then "flaked" for pigment by grinding in ball mills. Copper powder made by atomization is burned to an oxide cake, and the ground oxide spread evenly on an endless belt going through a long muffle wherein the mass is first reduced to metal in a gas atmosphere and then cooled to room temperature. The operation of atomizing is particularly interesting for its simplicity; molten metal is sucked up through a small central orifice and spreads out on the flat nozzle-end until it meets a cylindrical wall of high pressure air coming through an annular orifice about $\frac{3}{8}$ in. inside diameter. Rapid expansion of this air refrigerates the trapped metal particles so rapidly that less than 0.5% oxide is formed. A considerable change in the mean particle size may be had by varying the temperature of the metal, the dimensions of the atomizer and the air pressure.

making & measuring metallic powders

Size measurement of such fine powders, 100% through 200 mesh and 70% through 325 (the minimum size of accurate screens) is an exceedingly interesting problem. Here again three methods are in use. The basic one is an actual count of particles in an enlarged shadowgraph — a slow method, subject to a large sampling error. The more usual laboratory method is due to ROLLER: an air stream blows across an agitated sample and the fractions that pass miniature cyclone catchers in a series of decreasing sizes are caught in respective porous capsules and weighed. The most rapid method is used for plant control; it is an adaptation of the Wagner turbidimeter standardized for cement testing, where a photocell measures at short intervals the light transmitted by a suspension of the powdered metal in oil.

HOT DIP GALVANIZING

a review of

the process

By Herbert R. Hanley
Professor of Metallurgy
School of Mines and Metallurgy
University of Missouri (Rolla)

HOT DIP GALVANIZING is the process of putting a layer of protective metal on iron and steel articles by dipping them into molten zinc. Three principal methods are now in use: *(a)* Hand dipping of irregular shapes, either singly or in baskets; *(b)* galvanizing of sheets by roller-feeding them one by one through zinc pots; *(c)* continuous or strand annealing of wire. In all cases the iron or steel articles are first cleaned of scale (usually by pickling in dilute sulphuric acid, washing, dipping in dilute muriatic acid, and drying), dipped, and the excess of zinc drained, shaken or wiped off.

Many factors affect the adherence of the coating, its thickness, appearance, tenacity and corrosion resistance. Some of these will now be briefly discussed, using for the most part the galvanizing of sheets as an example.

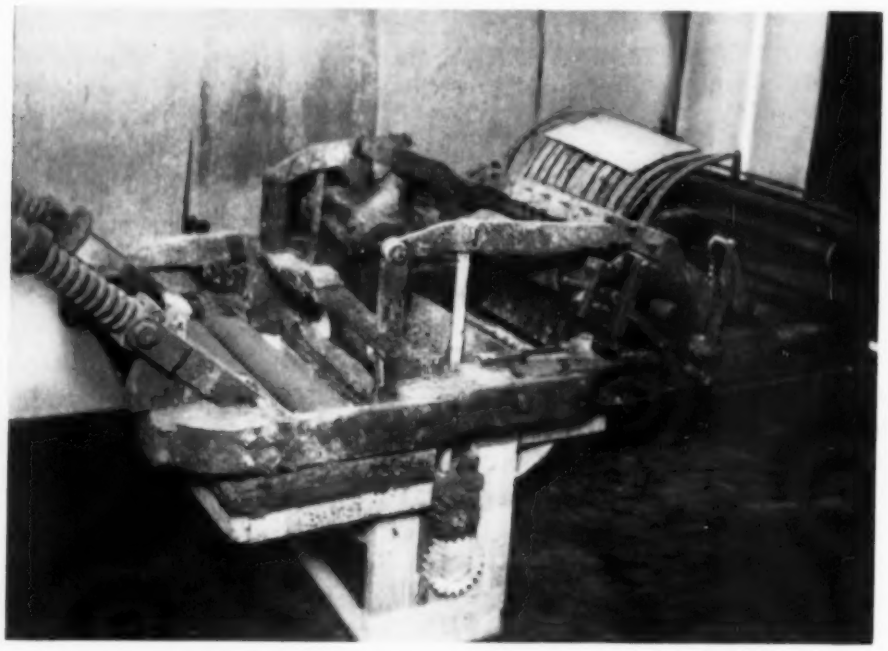
A Complex Coating — The cross section of a hot dipped zinc coating shows the well-known multiple-layer alloy structure between the steel and the zinc, brittle when thick and causing the coating as a whole to crack when the galvanized sheet is sharply bent. The layer next to the steel sheet is sometimes called the Fe_3Zn_{10} compound. This layer, sometimes invisible, is extremely thin. Next to this is the iron-zinc alloy usually named $FeZn_7$; it is always present, and forms an irregular boundary with the outside zinc layer which has approximately the composition of the zinc bath. (These materials have, in fact, variable percentages of iron. Fe_3Zn_{10}, theoretically 20.5% Fe, may analyze from 20 to 27%, and $FeZn_7$ from 7% up to its theoretical 11%.)

The solubility of iron in liquid zinc is extremely limited. Excess iron forms the compound $FeZn_7$ and sinks to the dross layer in the galvanizing pot. When these crystals are very small they may temporarily float ("floating dross"). Source of the iron for the dross will be discussed below. Although the zinc bath always contains sufficient $FeZn_7$ to be visible under the microscope, the outside layer of zinc on the galvanized sheet seldom discloses its presence; this observation indicates that iron in the zinc layer is extremely small.

W. M. Peirce, addressing the American Zinc Institute in 1938, said that the ductility (bending properties) of the coating lies largely in the smoothness of the boundary between the alloy layer and the outer zinc layer. Likewise, the smoother and cleaner the steel surface the less rapidly and less irregularly the alloy layer grows. This indicates the need for thoroughly washing the pickling salts and sponge iron from the surface of the steel to be galvanized. For instance if a piece of steel is buffed and immediately galvanized without pickling, the $FeZn_7$ layer will appear just as dense as the Fe_3Zn_{10} layer which is sometimes visible next to the

steel surface, and the boundary below the zinc layer will be a straight line. Such a coating has remarkable bending properties. It has been the observation of many, probably all, galvanizers that freshly rolled sheets yield better bending properties after galvanizing than sheets which have rusted in storage and so required more severe pickling; the heavier pickling gives a rougher surface on the steel and is reflected in a more irregular layer and poorer bending properties.

Mr. PEIRCE also reported that if a clean steel sheet is passed through a 25% $ZnCl_2$ solution instead of the common HCl solution before entering the zinc bath, best results are obtained with reference to the thinness of the alloy layer and to the ductility of the entire coating. When the steel surface is not cleaned from $FeCl_2$ or pickling products, the salt is reduced to sponge iron by the action of the molten zinc (a prime source of iron for dross in the zinc pot) as well as covering the steel surface with irregular jagged points of alloy notching on the underside of the zinc layer, and affording innumerable starting points for cracks when the coated sheet is bent.



Galvanizing Machine, Removed From Zinc Pot. Sheet is fed down diagonally between rolls at left, goes between submerged rolls (end gears, only, shown), up and out under curved guides to "wringer" at extreme right

Source of Dross — Precise allocation of the quantity of dross between its various sources is not easy. Comparing the quantity of dross discharged from the zinc bath during the life of the pot with the dross formed from the iron lost from the pot indicates that this source accounts for only a small per cent of the total. Likewise, if the iron salts and sponge iron formed during pickling are thoroughly removed from the steel going into the galvanizing bath, the dross can be reduced to a very small amount. However, thorough washing of the bare steel sheets is not current practice.

Oxidation of Zinc — W. H. SPOWERS in his recent book on "Hot Dip Galvanizing Practice" (Penton Publishing Co., Cleveland) stresses the loss of zinc by oxidation. In a wire galvanizing plant approximately 1100 lb. zinc is oxidized per sq.ft. of bath surface per year (about 10% of the new zinc introduced). Similarly in a pipe galvanizing plant the figure is about 28,000 lb., representing 25% of the new zinc used. Since there is about 100,000 tons of new zinc used in these two fields, this economic loss is very important.

The area of the zinc bath at which the steel enters is generally covered by a flux, but the exit area is not generally protected. At this point, proprietary granular materials may be spread to a thickness of ½ to 1 in. Such commercial materials are available; they should not burn, char, flash, melt or cake.

Fluxes, from a metallurgical viewpoint, are substances used to promote the fusion of materials. Historically, they are used more specifically in hot galvanizing to promote alloying of molten zinc with solid iron or steel by cleansing the surface.

While the oxides on the surface of the steel are removed by pickling, that is, immersion in dilute acid, modern fluxes are prepared to maintain a clean surface of the steel just prior to its immersion in the molten zinc. Some form of ammonium-zinc chloride is generally used. Pure ammonium chloride cannot be used because its boiling point is below the melting point of zinc. Since volatilization of a mixture

of ammonium and zinc chloride in practice is nominal, it is implied that there is a complex form of combination which has a low vapor pressure. Modern practice replaces the old sal ammoniac additions to old flux by substituting a commercial mixture of complex compounds of zinc and ammonium chlorides. SPOWERS says that zinc-ammonium chloride forms two double salts. One form contains 1 mol $ZnCl_2$ and 2 mols NH_4Cl; the other is combined in the ratio of 1 to 3 mols. The latter crystalline compound does not absorb water readily, is stable and is preferable as a flux.

Flux changes in composition during use. A good one, originally about 42% Zn, 7.5% NH_3 and 50% Cl, becomes undesirable when the analysis shifts to 50% Zn, 2.5% NH_3 and 46% Cl.

Zinc chloride solution (25%) or zinc-ammonium chloride in 1 to 1 molecular ratio is used as "flux-wash" following the pickling and washing of the steel. Its duty is to provide a film on the steel capable of retarding oxidation during its travel to the zinc pot. The successful use of zinc-ammonium chloride, both as flux-wash and as a molten kettle flux for ideal practice is embraced in the following description:

First, thorough pickling to secure clean iron or steel surface; second, thorough rinsing in cold running water to remove soluble iron salts or free acid from the steel surface; third, immersing the metal in the flux-wash; fourth, passing it through the molten zinc-ammonium kettle flux floating on the molten zinc, and thence into and out of this zinc.

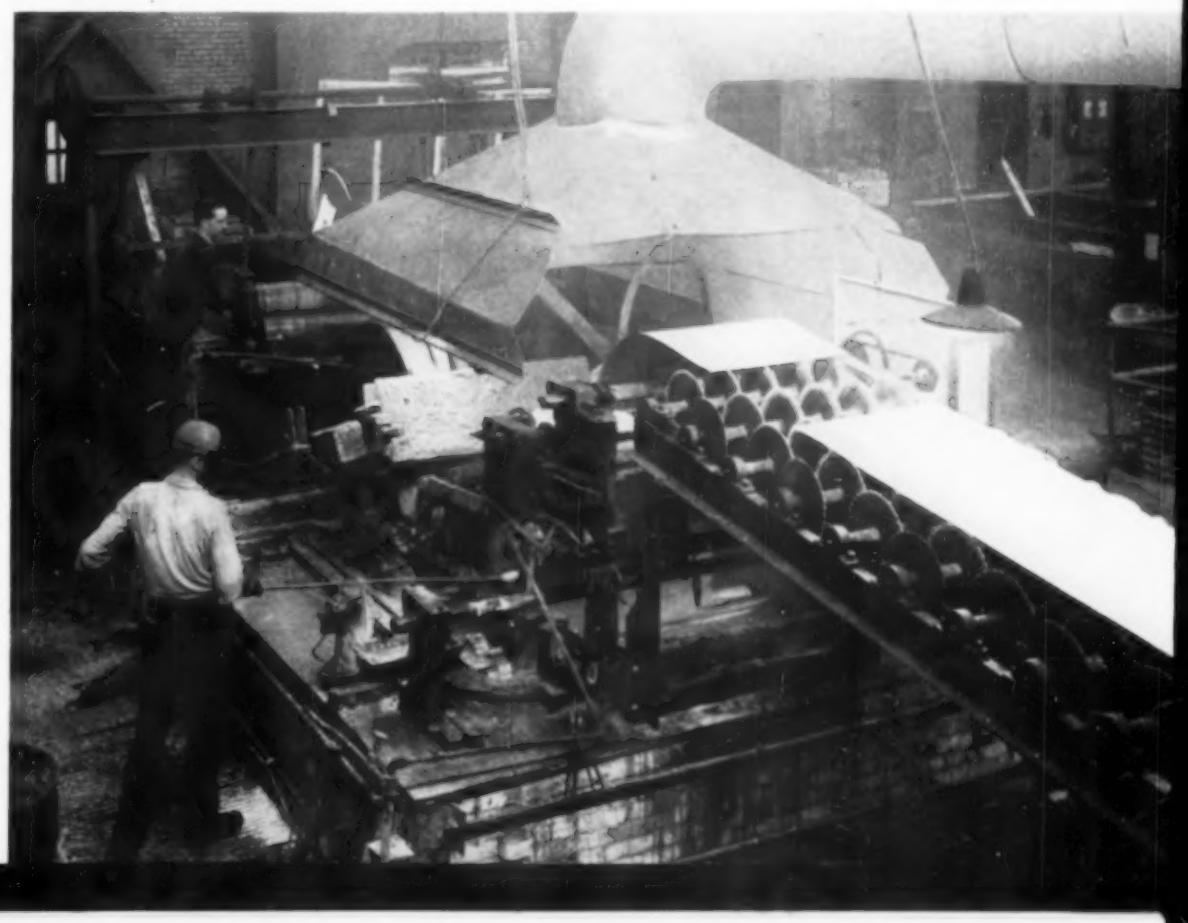
Alloys in the Zinc Bath — Metals commonly present in the bath other than iron are cadmium and lead; these vary in amounts according to the grade of spelter purchased. Commercial zinc ranges in purity from "Prime Western" which according to the American Society for Testing Materials specification may contain up to 1.6% lead, or "Selected" with up to 0.75% cadmium, to "Special High Grade" with no more than 0.01% total impurities.

Except for extremely heavy plates, thickness of coating depends both on temperature and length of immersion, and also on the nature of the components of the bath. Fluidity is necessary, and since the temperature must be regulated to a reasonable low point the fluidity must be controlled by bath composition.

Corrosion of Zinc — Zinc coated sheets are protected from natural corrosion by the presence of oxidized compounds which form over the surface. These compounds result from the hydroxide, initially formed in storage, combining with the carbon dioxide present in the atmosphere to form basic carbonate. Any condition which interferes with the absorption of carbon dioxide and oxygen fosters the growth of hydroxide and the corrosion of the zinc coating.

Examples of this type of corrosion are realized when galvanized sheets are piled flat and exposed to damp weather or changes in temperature. This trouble has been solved by the "Cronak" process, patented by the New Jersey Zinc Co., which consists of removing the oil or grease by an appropriate solvent, cleaning in dilute HCl, and dipping for 10 sec. in a solution containing a dichromate, rinsing and rapid drying at low temperature.

Effect of Steel Composition — Great difficulty is experienced in securing a ductile heavy zinc coat on pure iron wire and steel of low carbon content when conventional practice is followed. A relatively new process for this is now in operation, known as the "Armco Zincgrip" process for continuous galvanizing of low



Galvanizing Pot in Action on Sheet, Delivering to an Elevated Disk Conveyor. Note liquid zinc turning to spangles near end of cooling sheet. Courtesy American Rolling Mill Co.

carbon steel or ingot iron strip. Its aim is to obtain a steel surface, prior to galvanizing, which is absolutely free from oxides. To get this a very thin layer of oxide is first formed and then reduced in an atmosphere of hydrogen at 1100° F. The flow sheet is as follows:

1. The strip coming from the cold mill is pickled if it contains heavy scale, otherwise it is not. If running at high speed, the steel may be moistened with water in order to accelerate the formation of a controlled oxide.

2. The strip enters an oxidizing oven, open at both ends, similar to a normalizing furnace, at a temperature of 700 to 900° F.

3. The strip then enters the annealing furnace through a gas-sealed slot where the oxides are reduced with hydrogen at about 1100° F. From this point on, the steel does not come in contact with the atmosphere until galvanized.

4. The strip leaving the annealing furnace passes through a long cooling chamber filled with reducing gas atmosphere. Any carbon dioxide or oxidizing gases which may seep in are removed from this cooling chamber by reaction with hot copper plates or hot iron filings placed in the chamber. The cooling chamber tapers and its end is immersed about 2 in. in the molten zinc which the strip enters at about 250° F. superheat. Thus the galvanizing takes place without exposure of the hot strip to the atmosphere.

5. The length of travel of the strip through the molten zinc is very short (about 12 in.) and the result is a coat which adheres tightly and contains a very low percentage of iron-zinc alloy between the steel and the zinc layer.

Wire galvanizing is a continuous process. The wire is drawn through successive pickling, annealing and washing operations which vary, depending on the practice of the plant. It is dried and then passes into the galvanizing pan, and is drawn out through charcoal, coke, sand or asbestos wipers.

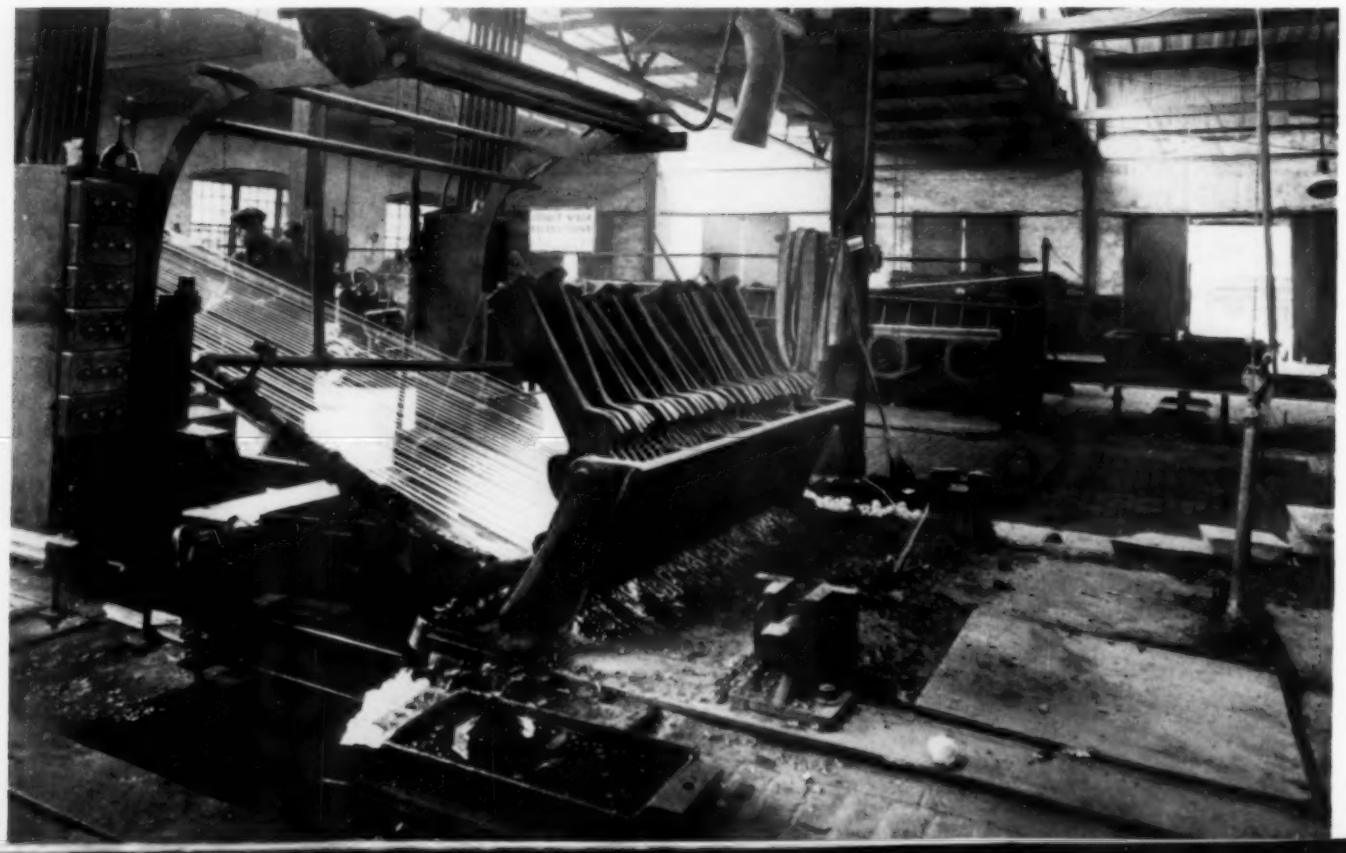
Hot dip processes in present use for wire are distinguished by the method of wiping: *(a)* Charcoal wiped, *(b)* flame smoothed coating and *(c)* asbestos wiped. (Electrolytic coatings are also laid on wire, using either soluble or insoluble anodes. See the article on "Bethanizing" in METAL PROGRESS, May 1937.)

Each process of coating lends itself to a wide range of variations such as specific methods of annealing the bare wire, cleaning and fluxing prior to coating, regulation of the coating weight, and the finish of the coating prior to or after blocking the wire into coils.

In the hot dipped, asbestos wiped process, hard drawn wire is placed on reels, annealed, cleaned, rinsed, fluxed, coated, wiped and wound continuously upon blocks which furnish the motive power for the process. The operation is made continuous by fastening the back end of one coil to the front end of the succeeding coil either by butt welding or by a double loop known as a joint. The finished product is removed from the blocks after cutting the wire near the joint while in motion.

Methods of wire galvanizing sometimes depend on the particular service for which the product is intended. In straight wire galvanizing the wire is first annealed either in double lead pans or open furnace, then pickled in HCl,

Wire Strands Entering Galvanizing Kettle. Courtesy Republic Steel Corp.



washed in clear running water, fluxed, galvanized, wiped and reeled. The temperature of the lead bath in the first pan is approximately 1000° F. for dead soft anneal and 1300° F. for a "semi-anneal". The lead in the second pan is held at about 1300° F. for dead soft anneal and 800° F. for a "semi-anneal".

Hydrochloric acid is universally used because of the speed of action required; the acid strength is adapted to the length of the tub, as is also the temperature. Additions of acid are made until the iron content reaches 0.5 lb. per gal. The temperature then should be sharply raised for a short period without further additions. This procedure will use all the free acid before dumping the solution.

Pickled wire is washed thoroughly in clear running water. It then passes through the solution of zinc-ammonium chloride flux wash; no special drying is necessary before entering the molten kettle flux. Sufficient flux is carried over on the wire to maintain a volatile bath at the entrance end of the pot and thereby prevent any accumulation of oxides. A dam at the entrance end keeps the flux from touching the sides of the pot, thereby lessening the rate of volatilization. A similar dam is placed just before the exit point of the wire where some blanketing material is placed to lessen the oxidation of the zinc.

For extremely bright, thin, decorative indoor coatings the wire may be immersed in the zinc at the lowest possible temperature for a short time, wiped and immediately water-chilled. For dull, heavy corrosion resistant outdoor coatings the wire may be immersed in the zinc for the full length of the pan at high temperature, cooled in air after leaving the wipe, and water cooled just prior to coiling.

Because of the brittleness of heavy zinc coatings, wire galvanized with pure zinc and wiped with charcoal wire may be subjected to heat treatment.

Conclusion — At present the sheet and wire galvanizing industries are in a dynamic state in comparison with their status several years ago. Operators maintain research staffs exploring better methods for conditioning the bare steel, methods for controlling temperature and oxidation of the bath, methods for controlled cooling of the coated product, and improvements in fluxing. A series of such improvements leads to greater adherence of the coating to the steel base during deformation and fabrication, as well as greater resistance to corrosion.

SLIDING, FRICTION

and vibration

By F. P. Bowden, L. Leben and D. Tabor

Abstract of "The Sliding of Metals, Frictional Fluctuations, and Vibration of Moving Parts", The Engineer, *Aug. 25, 1939, p. 214*

RECENT EXPERIMENTS at the Laboratory of Physical Chemistry, Cambridge University, have shown that sliding between metals is not a continuous process, but may proceed by "stick and slip". To measure this, the equipment must have low inertia and use high speed recorders. In our experiments a flat metal plate was driven slowly by hydraulic piston under a small curved metal piece.

Three distinct types of sliding have been observed. Type I occurs when a hard, high melting point metal slides on a softer one of lower melting point — molybdenum on steel, for instance. An autograph of frictional resistance against time is saw-toothed, resistance increasing steadily from 0.38 to 0.40 for 1/3 sec. (0.001 cm. of travel in these experiments) and then instantaneously dropping back to 0.38. Except in the instantaneous slip there is no relative motion at the very surfaces; they are sticking together until suddenly a very rapid slip occurs. When the tangential force has fallen to 0.38 the surfaces again stick, and the process is repeated indefinitely. Under the microscope it was found that a well-defined track was torn out of the softer metal.

In Type II, which is characteristic of a low melting metal sliding on a harder one of higher melting point, like bearing metal sliding on steel, the motion also is by stick and slip, but the slips are much larger. Resistance increases steadily from 0.20 to 0.50 for 1.7 sec. (0.005 cm. travel) and then drops instantaneously to the lower figure. The high melting metal is undeformed, but small blobs and smears of the low melting metal are wiped onto it.

When identical surfaces slide together (Type III) friction is very much higher, 1.4 to 1.5 for silver on silver, and fluctuations are much slower and very irregular. The nature of the track is also different; a groove is formed in the flat surface, but it appears as though it had flowed during sliding and then solidified.

Experiment has also shown that even if the surfaces are lubricated the behavior may be essentially the same and an intermittent clutching and breaking away of the metallic surfaces occurs through the oil film.

The area of the contacting surfaces may be estimated from the electrical conductance, and may be less than 0.0001 of the apparent area. No surface is quite flat, *(Continued on page 452)*

CORRESPONDENCE

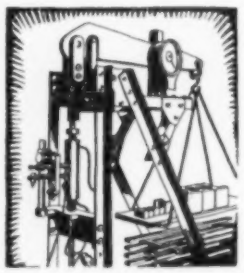
from home and abroad

Irregularities in Creep Tests
possibly due to tremors

PITTSBURGH

To the Editor of METAL PROGRESS:

During the past few months my attention has been brought directly to bear on a large amount of experimental test data on the subject of creep. In examining these data it has been noted that in several instances tests, which have covered very long periods, not uncommonly show abrupt changes in certain parts of the curve which seem to be without explanation on any of the metallurgical bases.



These peculiarities seem to indicate that the attention of investigators of this phenomena should be pointed toward the effect of earthquake waves. Most of the tests are made by dead weight loading methods which would readily be subject to the effects of the vertical components of these seismic influences. The magnitude of these waves could put appreciable additional loads on the test specimens, and it would be interesting if these data could be correlated with such geodetic effects by way of removing one of the doubtful points regarding some sharp deviations in creep data.

D. E. BABCOCK
Industrial Fellow
Mellon Institute of Industrial Research

Heat-Tinted Microsections
of non-ferrous metals

IPSWICH, ENGLAND

To the Editor of METAL PROGRESS:

Some years ago the writer became interested in the heat-tinting of non-ferrous metal specimens, instead of the usual acid or similar dip-etch treatment, as a means of identifying the various structural constituents. In a number of cases heat-tinting proved to be very satisfactory.

The method is cleaner than the dip-etch procedure, though it takes a rather longer time; furthermore, where there is unsoundness due to blow-holes or porosity such areas can usually be examined more satisfactorily, since there is no danger of etching solution staining the specimen or "seeping back" over the surface when the specimen is being dried.

It should be pointed out that sometimes there may be a very slight polish-etch resulting from attack of the last stage of polishing on the specimen during the final preparation; provided this is not excessive there is no confusion likely to arise, and as a matter of fact a very slight polish attack rather enhances the structural definition.

Recently an opportunity arose for the writer to have one of his assistants investigate further this heat-tinting procedure. Some of his photomicrographs might interest readers of METAL PROGRESS, particularly those who are able to link up color photography with such a method of examination. Actually we have not yet had an opportunity of following this latter development in metallography.

Briefly the procedure employed was as follows: The specimens were cut from the grip-ends of unbroken tensile test bars (with one exception; in the latter case the test specimen was cut from an area in the region of fracture of a tested test bar) and were about ¾ in. in diameter. They were all polished in the usual way — that is, on progressively finer grades of emery paper and finally by ordinary liquid metal polish. Heat-tinting was carried out without any previous etching of the specimens. The specimens were freed from grease by washing in pure carbon tetrachloride.

They were then floated, polished side uppermost, in a shallow trough of molten tin which rested on a small electric hot plate. The tin was uniformly heated and in most cases maintained at a temperature of approximately 280° C. For the nickel alloy and manganese brass a higher temperature of approximately 360° C. was required to give suitable tinting conditions. When a purple tint was obtained over the whole area, the specimen was withdrawn from the tin and quenched by floating in a shallow trough of cold mercury. At this point it is very necessary to avoid touching the heat-tinted surface of the specimen with the mercury.

It is sometimes necessary to repeat, for a short time, the operations outlined above until a tint of satisfactory depth is obtained. This was particularly found to be the requirement with high nickel alloys and manganese brass. For these two materials about one hour's treatment is necessary, while the other specimens only require from 3 to 6 min. immersion.

H. H. SHEPHERD
Chief Metallurgist
Nacton Works; Crane, Ltd.

Extras for Aircraft Quality Steel

NEW YORK CITY

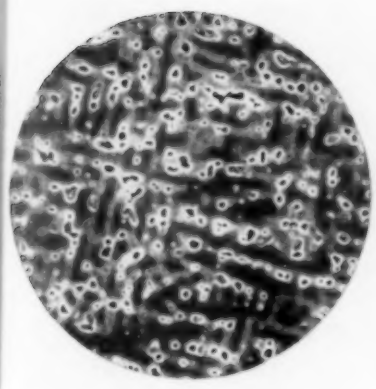
To the Editor of METAL PROGRESS:

May I call your attention to a statement which appears under "Critical Points" on page 161 in the February 1940 issue of METAL PROGRESS, which might possibly be misread.

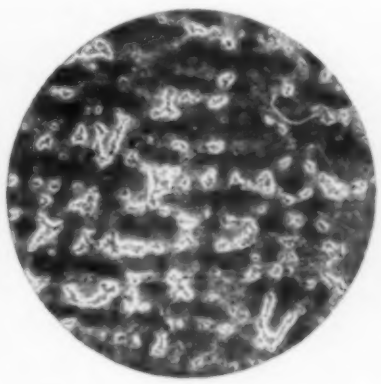
The statement in the item entitled "Superfine Metals for Air Engines" concerns requirements of the consumers, and is: "But really, these are already so severe that the standard extra for steel of 'aircraft quality' (in accordance with the American Iron and Steel Institute procedure) is charged largely to cover the extraordinary amount of acceptance testing."

During the period when the Code of Fair Competition of the Iron and Steel Industry was in effect the list of Uniform Extras and Deduc-

Heat-Tinted Non-Ferrous Castings; Structure Magnified 75 Diameters



No. 5 Gunmetal
86-6-2-6 Red Brass



Phosphor Bronze
89% Cu, 11% Sn, 0.4% P

Cast Manganese Brass
Additions: 1.3% Fe, 0.5% Pb, 0.5% Sn, 0.5% Al, 0.4% Mn

Nickel-Copper-Tin Alloy
32% Ni, 11% Sn, plus a little Mn, P, and Fe

tions for Products of the Iron and Steel Industry showed, on page 9 of Section 29, certain extras for alloy steels of special aircraft quality. However, since the termination of the Steel Code in May 1935, this Institute has not published, distributed or been otherwise interested in such extras. For that reason the reference to the Institute in the above quoted statement is inaccurate and misleading.

WALTER S. TOWER
Executive Secretary
American Iron and Steel Institute

EDITOR'S NOTE: — Each item in "Critical Points" attempts to cram a lot into a little space, with consequent inability to be explicit. The approximate situation concerning "aircraft quality" steels is that extras are charged for alloy and for unusually close chemical tolerances, and these extras for some reason or other are usually the same no matter what steel maker is quoting. Procedures and charges for such special work as macro-etching and magnaflux testing are matters for individual discussion and agreement between vendors and purchasers.

Endurance of Valve Springs
a correction

In the note on "Endurance of Valve Springs" by ALBERTO OREFFICE in the issue for December 1939, the text is at variance with the column headings in the table. The table is correct and the text should read . . . "endurance limits (established for stress between no load and maximum torsion)."

No Mystery in Arc Welding

CLEVELAND

To the Editor of METAL PROGRESS:

Arc welding has too many doctors. An operation which is perfectly natural, very simple and very easily accomplished, has largely been changed in the minds of the public to an art which takes on the mystery of voodooism with an admixture of the art of the medicine man.

The public is beginning to think that the welding operator is a cross between a miracle man and a professional musician. This opinion is groundless. The only thing that a welding operator can do is to hold the end of an electrode at a certain distance above the deposited metal and advance it along the seam to be welded at a certain speed. There is nothing more than this that is involved in the operation. It is neither complicated nor difficult. As a matter of fact, with proper electrode, proper setting of the welding machine and proper preparation of the work, it is practically impossible to make a weld which will not stand up in service without having it so evident to the inspector that he would immediately reject it. It is possible to have defects in the steel that cannot be seen which will make a steel structure dangerous; it is impossible, however, to make a weld on that structure which is dangerous without its being fairly obvious to anyone looking at the weld.

The reason we hear so much about the necessity of skill and care in welding is largely because the operation itself is so simple that it is difficult to find much about it to discuss in papers, lectures and statements. Therefore, many of these eccentricities which are volubly discussed consist of theoretical possibilities which exist only in the minds of the lecturers and seldom exist in reality.

It is time we get away from trying to make this very simple operation mysterious. It is time we recognize the fact that the metal deposited by the shielded arc electrode is definitely better than the parent metal it is joining. It is time we recognize that there has never been a failure on an insured pressure vessel made by the shielded arc process. It is time we recognize that, in the usual design, if only half a weld is made it will withstand all of the normal requirements of the structure. It is time we recognize that failures never occur in welds that are made by the methods recommended by any reliable manufacturer. It is time we recognize that there is no mystery in welding and that making a welded joint is far more simple than driving a riveted joint and more simple than making the steel which is joined together by this process. It is time we recognize that to spend time, money and attention in removing the least possible flaw from the deposited metal is silly in the light of the obvious flaws which must occur in the parent metal. A factor of safety is used to guard against these flaws that is

more than is needed for any commercial weld.

When we do recognize these facts we will have done two things: First, we will have given the green light to one of the most economical processes now known for the production of many structures. Second, we will have removed one of the fears which the uninitiated have developed regarding a perfectly normal manufacturing operation.

JAMES F. LINCOLN
President
The Lincoln Electric Co.

A Ghost

Mistress Prudence Godley Enjoying a Windy Afternoon on the Bleak New England Shore. Or is it a case of arrested development, discovered by Edmund S. Davenport in the U. S. Steel Corp. Research Laboratories, at Kearny, N. J.?

Welded Valve Bodies

TURIN, ITALY

To the Editor of METAL PROGRESS:

Over a year ago (December 1938) I wrote you concerning an interesting new development in high pressure valves. The good practical results obtained with these early valves, made from stamped and welded plates according to the Santamaria patents, have been fully confirmed both by a series of very severe and complete laboratory tests performed under the supervision of Lloyd's Registry, and by results in extensive applications in various technical fields.

In addition to the regular static deformation and breaking tests at normal and at high pressures and temperatures, the above-mentioned laboratory experiments included a comprehensive series of pulsation tests.

Static tests, made with steam at 75 atmospheres (1100 psi.) gave unexpectedly good results, especially for creep resistance. Valves designed for 850 psi. pressure and 800° F. (and weighing 40% less than the corresponding cast steel valves) were tested hydraulically at 2850 psi., and submitted in regular service to pressures exceeding 1400 psi. at 850° F.

Tests were also made with an especially designed pulsometer at maximum pressures exceeding twice those of normal service. For valves of regular dimensions the pressure limits were 950 psi. and 32 cycles per min. The elastic deformations showed the effects of water hammer, a value which was difficult to determine, but the resistance of the valves was perfect after 500,000 to 2,000,000 pulsations, even when completely neglecting to provide for water hammer.

Due to the excellent results of laboratory tests and of the first practical applications, the new type of valve has been definitely adopted for a great number of applications where technical requirements are especially severe, as for instance in oil distillation and cracking plants and in high pressure naval engines.

These applications have brought out other advantages of welded valves, in addition to those already known — that is, their low weight, low cost and high impact resistance. Among these is a very peculiar one, especially for naval applications, which lies in the fact that the welded valves can resist much greater elastic deformations than the safe limit for cast steel valves. This is a prime consideration toward the general safety of a steamship. The Santamaria valves have therefore been adopted by the Royal Italian Navy.

The same property has also proven to be of great importance in avoiding valve breakages in pipe lines subject to freezing or to rapid changes of temperature.

The manufacturing processes used for steel valves are at present adopted for bronze valves, where a strong non-ferrous alloy is necessary, and the results are as good as for steel valves.

FEDERICO GIOLITTI
Consulting Metallurgist

Variations in European Specifications for Iron Castings

DARLASTON, ENGLAND

To the Editor of METAL PROGRESS:

The subject of the international standardization of testing methods for iron castings discussed by Dr. FEDERICO GIOLITTI in your issue for January 1940 is one which has occupied the attention of The International Committee on Methods of Testing Cast Iron for a number of years. This committee, which was formed some years ago, with Professor PORTEVIN as honorary president, numbers amongst its members representatives from most of the European countries and the United States of America. The inception of the committee and its continued activity owe much to the interest and enthusiasm of Professor PORTEVIN, and M. LEONARD of Liege, who continued in the office of active president until 1938.

The International Committee on Methods of Testing Cast Iron has met regularly once a year on the occasion of the International Foundry Congress, the last meeting having been held in June 1938 in London, under the chairmanship of the writer. Since the individual members of the International Committee are nominated by the foundry association or institute of the particular country they represent, it has been possible to review the methods of testing adopted in each country in an authoritative manner. A report on the position of the methods of testing cast iron was produced by M. LEONARD, which will be found published in full in *La Fonderie Belge*, No. 52, January-February 1938, pp. 654 to 694. It will be apparent that the conditions which prevail amongst the European countries at the present time prevent the continued activity of this committee.

It ought to be pointed out that a considerable amount of investigation has been devoted to the testing of iron castings by individual workers and sponsored by the foundry associations in the various countries throughout the world. This has resulted in a clearer and wider understanding of the principles and conditions of testing as applied to cast iron. In the light of all this work I am of the opinion that Doctor GIOLITTI is inclined to exaggerate the importance and significance of the variations to which he refers.

J. E. HURST

Active President, The International Committee on Methods of Testing Cast Iron

20-Roll Mill for Thin Strip

HANAU, GERMANY

To the Editor of METAL PROGRESS:

With much interest we have seen, in METAL PROGRESS for November 1939, the picture on page 622 of a small 20-high mill. In the legend you refer to the issue of July 1939, where a brief description of this mill is given on page 33.

It will interest you to know that the mill described was designed and built by Heraeus-Vacuumschmelze A.G., Hanau M., Germany, and delivered to the United States, and that details of this machine were described in *Stahl und Eisen*, Vol. 52 (1932), page 821, in an article entitled "Anwendung kleinster Walzendurchmesser und Fortbildung von Mehrrollenwalzwerken," and in *Metallurgia* for December 1932, on "The Use of Small Roll Diameters and Development of Multiple-Roll Mills". The design of the machine is subject to American patents No. 1,903,724; 2,085,449; and 2,150,340.

In the meantime larger units have been built for rolling strip up to 24 in. wide at speeds up to 1000 ft. per min. An interesting feature is that the tolerances over the width and over the length of the strip rolled are unusually low. Strip 24 in. wide can be rolled to 0.002 in.; strip 12 in. wide to 0.001 in.

We would be glad if you could mention that this special rolling process and the 20-high mill was invented and first built by Dr. W. ROHN of Heraeus-Vacuumschmelze A.G., Hanau/M., Germany.

WILHELM ROHN

Heraeus-Vacuumschmelze A.G.

Properties Reflect the Structure

PARIS, FRANCE

To the Editor of METAL PROGRESS:

The most interesting general result, from the theoretical as well as the practical point of view, of investigations on metals and alloys is the correlation of their properties with their structure, by considering the latter in all its degrees and aspects.

The magnification under which the structure is observed might for the sake of clarity be classified in two groups: *(a)* Macrographic and micrographic structures, whose dimensions are measured by the millimeter and the micron, whose instrument of study is the microscope, and whose structural element is the crystal or grain; and *(b)* crystalline and atomic structures,

whose dimensions are measured by the Ångström unit, whose instrument is the spectrograph and whose structural element is the atom. The atom, according to the present concept, is formed of a nucleus accompanied by its group of electrons oscillating about mean positions; atoms are regularly distributed in the crystalline lattice, and some electrons move freely about through the lattice.

The structure formed by the lattice is the crystal, which may be either irregular or granular, dendritic, regular or geometrical in exterior form; in the aggregate this forms the micrographic structure. The inner structure of these crystals may be identical or of more than one variety, depending on whether they belong to the same phase or micrographic constituent. Sometimes it is possible, as in ferrous alloys, to distinguish the macrographic structure by means of the micrographic structure formed by transformation in the solid state, which leaves the skeleton or indication of past organization or crystallization. The macrographic structure of steel is the structure of solidification (sometimes deformed by forging) and it is replaced by the micrographic structure when cooling through the transformation range in the solid state.

Between the micrographic and the crystalline structures may be placed the so-called mosaic structure, which divides the crystalline unit into particles that are not rigorously oriented like the bricks of a building. According to this concept the crystal might present periodic imperfections or discontinuities, so that the ideal, uniform lattice is not realized throughout the entire grain.

We have attempted to correlate the various properties of metals and alloys, as well as the principal facts and phenomena that have been observed, with these various degrees or aspects of the structure, by drawing up the accompanying table. This table, of course, is only a first approximation and an arbitrary simplification; in principle, the properties and phenomena mentioned depend on the structure in all of its degrees or aspects, particularly since the various degrees or aspects are interdependent. Thus, the crystalline structure adapts itself to the atomic, and the various micrographic constituents depend on the crystalline structure.

However, it seems that certain properties or phenomena depend largely, if not exclusively, on a definite category or a particular aspect of the structure, and within the same structure the properties may depend even more specifically on certain structural characteristics.

Thus, while the free electrons seem to be responsible for electrical conductivity, thermionic, photo-electric and Volta effects, the valence electrons seem to govern the formation of intermediate phases or definite intermetallic compounds and to determine both atomic volume and the limit of solid solubility.

According to Forrer, a rather narrowly defined value for the atoms appears to be a necessary condition for ferromagnetism, and

Interrelation of Structure and Properties

Scale of the Structure	Principal Phenomena Related to Structure
Macrographic structure	Relation between cooling factors and solidification structure. Primary dendritic segregation. Heterotropy of forged steels; transverse mechanical properties.
Micrographic structure	Most properties of aggregates of more than one constituent (variations in hardness, malleability, corrosion, structural brittleness). Machinability. Properties of eutectics (hardness, castability . . .). Structural hardening. Intergranular cracking. Aging of steel. Hot hardening. Forgeability. Transformation phenomena and condition of steels after hardening, tempering, annealing. Variations of physical properties with composition.
Mosaic structure	Differences between calculated and experimental mechanical properties. Dimension of figures of corrosion and spacing of slip planes.
Crystalline lattice	Crystalline deformation and cold work. Various types of rupture. Various types of solid solutions, and methods of attaining them. Corrosion of solid solutions.
Atomic structure	Conditions necessary for solid solution. Nature, classification and specific properties of definite components (hardness, conductivity . . .). Electrical conductivity, magnetic properties. Curie point and fusion point.

the number of electronic orbits is related to the CURIE point, which in turn is related to the fusion point. Certain magnetic properties, however, are sensitive to the slightest deformation of the crystalline lattice.

The modulus of elasticity appears, on first approximation, to be an atomic property depending on the nature of the atoms and of the interatomic bonds — hence its relative constancy despite modifications of micrographic, macrographic and even crystalline structure. On the other hand, mechanical properties or characteristics are influenced by modifications of both the micrographic and macrographic structure, while electrical conductivity depends chiefly upon the nature, proportion and mutual solubility of the various constituents.

Hardening of quenched alloys by tempering, either by mild heat or spontaneously at room temperature (aging) may be related:

(a) Either to the precipitation of very fine particles along the main crystallographic cleavage planes in a Widmanstätten pattern — that is to say, related to the micrographic structure; or

(b) To a particular crystalline organization (superstructure), or to a special distribution of the atoms in the lattice (atomic masses following preferred crystallographic planes — that is to say, related to the crystalline structure.

Thus the hardened state of metal may be an annealed condition with a metastable micrographic structure (such as troostite in steels, the light alloys of aluminum, magnesium and silicon), or it may be an intermediate crystalline state not represented on the equilibrium diagram (martensite in steels, Al-Mg and Al-Cu light alloys).

The table is thus only a very imperfect and provisional outline, but it is by this knowledge of the dependency and hierarchy of properties and structures that researches may be organized. It will eventually be possible to construct an alloy having definite properties, just as an architect or an engineer constructs a building or a machine for a predetermined purpose.

This conception of superimposed structures of various degrees of fineness or coarseness governing the properties is not peculiar to metals and alloys. Likewise various "stages" of structures — atomic, molecular, colloidal, macroscopic — must be considered in order to understand fully the properties and transformations of natural fuels, for instance coal. The same is true in the study of cellulose and its derivatives.

ALBERT PORTEVIN
Professor
Ecole Central des Arts
et Manufactures

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THIS IS HOW:

1 Lowers initial cost
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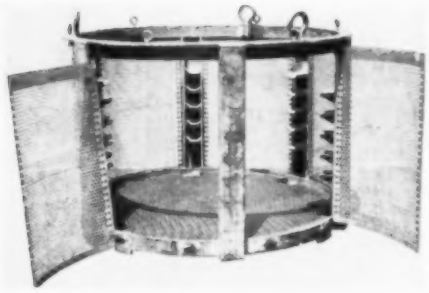
5 Saves time in handling and loading
6 Reduces pot cost per hour
7 Outlasts average cast alloy equipment.



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WILKES-BARRÉ, PENNSYLVANIA

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PERSONALS

John M. Kiefer, Jr. is now assistant works metallurgist, Cuyahoga Works, American Steel & Wire Co., Cleveland.

Transferred by Doehler Die Casting Co.: **E. J. Basch**, from Pottstown, Pa., to Batavia, N. Y., in the metallurgical department.

R. S. Kerns, formerly research metallurgist at the Union Carbide and Carbon Research Laboratories in Niagara Falls, has been transferred to Chicago as metallurgist with the Oxweld Railroad Service Co.

Cecil H. Desch has retired from the National Physical Laboratory and is now acting as scientific adviser to the Iron and Steel Research Council, London, England.

Market Tip

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The 12,000 Metal Progress subscribers are acknowledged the Number One metallurgical market in this country.

It should be interesting to manufacturers who sell this market, therefore, to learn that a survey is just being completed which shows what equipment and supplies these men plan to buy during the coming months.

If you want to get a better picture of the vast market which can be tapped through advertisements in Metal Progress — put in a reservation today for your copy of this survey which will be released shortly.

Address:

METAL PROGRESS
The Monthly Magazine of
The American Society for Metals
7301 Euclid Avenue
CLEVELAND, OHIO

Kenneth A. De Longe has been transferred from the research laboratory of International Nickel Co. in Bayonne, N. J., to the development and research department in New York.

John S. Roberts, formerly with the Florence Pipe Foundry & Machine Co., is now chief metallurgist of the American Manganese Bronze Co. at Holmesburg, Pa.

R. L. Moncrief has left the American Rolling Mill Co. and is now metallurgist at Plant No. 2 of the Frigidaire Division of General Motors Corp. at Dayton, Ohio.

Joe S. Thompson has been appointed district sales manager of the Chicago office of The Babcock & Wilcox Tube Co.

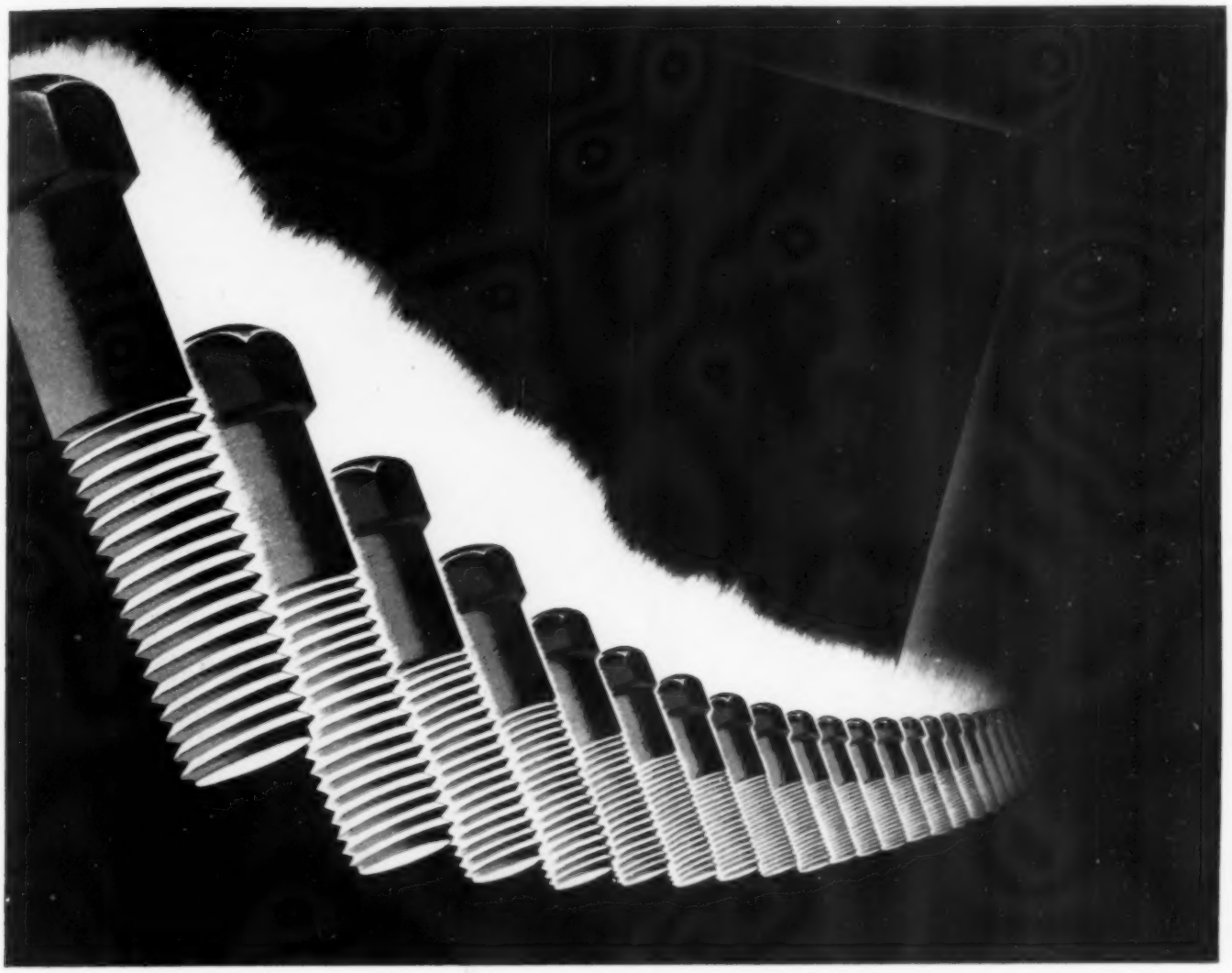
William B. Lawson, formerly of the Harshaw Chemical Co., has announced the formation of W. B. Lawson, Inc., dealing in industrial chemicals, oil, and nonferrous metals with offices in Cleveland.

R. M. Terry is now divisional industrial representative for Shell Oil Co., Inc., with headquarters at East Providence, R. I.

Leonard P. Rice has left the metallurgical laboratory of the South Works of Carnegie-Illinois Steel Corp., to take an assistantship in the department of metallurgy at University of Notre Dame.

Harold M. Foster, formerly manager of tool and alloy steel sales for Faitoute Iron & Steel Co., is president of a newly organized concern, Foster Steel Treating Co., with plant and office in Newark, N. J.

Frank D. Masino, formerly with Aluminum Co. of America, is now with Eclipse Aviation Corp. of Bendix, N. J., as a tool designer.



QUALITY UP—COSTS DOWN

When a change in material specifications reduces fabrication costs, and at the same time turns out a better product, there's something for everybody to cheer about.

Molybdenum steels are doing just that in many instances. Many manufacturers, for example, standardize on Chrome-Moly (SAE 4140) for bolts. Easier machining brings economies in tool expense and machining time—not much per bolt but a big saving in the aggregate. And the better physical properties of the steel bring better service performance in the product.

There may be places in your own specifications where the use of Molybdenum steel will simplify production, improve the product or both. Our book "Molybdenum in Steel", is filled with practical data which will help you recheck your specifications. It is sent free on request to interested production engineers and executives.

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MOLY

PERSONALS

J. G. McCallum, chairman Golden Gate Chapter, formerly metallurgist for the Marchant Calculating Machine Co., has opened a laboratory and consulting office in Oakland, Calif.

L. G. Greenman has retired from active service as president of the Greenman Steel Treating Co., which has been purchased by the New England Metallurgical Corp., Boston, and will henceforth be known as the Worcester division. **A. Dudley Bach**, president, new England Metallurgical Corp., is taking over Mr. Greenman's duties, and **Lloyd G. Field**, formerly superintendent of the heat treating department of the Trimont Mfg. Co., is in charge of the Worcester division.

Appointed to the staff of Battelle Memorial Institute, Columbus, Ohio: **Robert H. Heyer**, formerly research metallurgist with American Rolling Mill Co.

Arden L. Knight, chairman Boston Chapter, formerly New England sales manager for Wheelock, Lovejoy & Co., has joined the sales force of the Hartford office of the Latrobe Electric Steel Co.

D. M. Curry has resigned from the development and research department of the International Nickel Co., Inc., to join the technical service staff of H. Kramer & Co., Chicago.

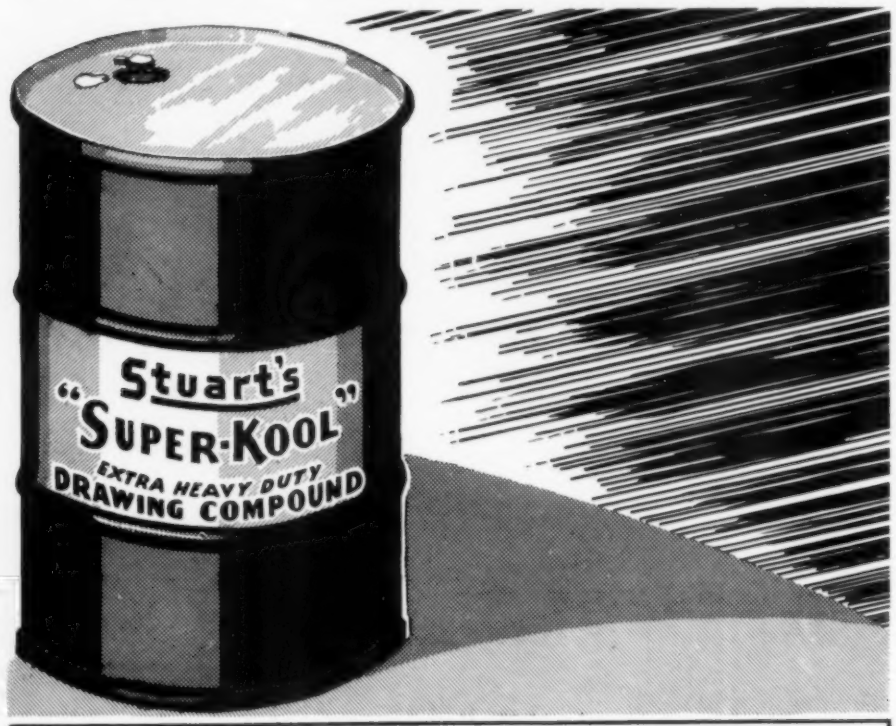
Honored: **Frederick M. Becket**, president of Union Carbide and Carbon Research Laboratories, Inc., and consultant, Union Carbide and Carbon Corp., by presentation of one of the Modern Pioneers Awards of the National Association of Manufacturers, and also by being selected to receive the Elliott Cresson Medal of the Franklin Institute in May.

Purdy F. Benedict, formerly vice-president and director of sales, Faitoute Iron & Steel Co., is president of the newly organized firm, Benedict-Miller, Inc., Newark, N. J., distributors of fine steels. **Harvey L. Miller** is treasurer.

F. J. Fieser has announced the purchase of Ensign-Reynolds Co. from American Radiator & Standard Sanitary Corp., the reorganized company to be known as Fieser-Lundt, Inc.

F. B. Cornell and **C. H. Knappenberger** have been appointed agents for the state of Michigan for the Duraloy Co., with offices in Detroit.

William J. Boyer has accepted a position as research chemist with the Rustless Iron and Steel Corp., Baltimore, Md., having resigned as assistant chief chemist with Carpenter Steel Co., Reading, Pa.



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Listed below are some of the types of furnaces we have built in the past 33 years. If you want an idea of just how we would solve *your* heat treating problem just drop us a letter today. It will put you under no obligation — and might result in an economical solution.

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"METALS"

(Continued from page 421)

iron alloys. Austenite is defined, of course, as a solid solution of carbon in gamma iron. Martensite is a solid solution of carbon in alpha iron, the latter strained into a distorted cubic lattice, in fact tetragonal. Pearlite is the mixture of alpha iron and cementite lamellae, more or less parallel, that forms directly from austenite during phase change at subcritical transformations Ar'. If conditions are right, a rapid cooling can trap austenite, untransformed down to 300° F. This austenite transforms into martensite only as the metal cools; if cooling stops transformation stops; hence retained austenite is stable. (This boldly stated proposition by the English teachers is clearly at variance with DAVENPORT and BAIN's S-curve for eutectoid steel.)

"Troostite is an aggregate resulting from the simultaneous formation of ferrite and cementite in such fine lamellae that either they cannot be resolved at all, or only with difficulty under high magnification." They say that troostite can originate in these ways:

I. During cooling of austenite at just less than the critical rate.

II(a). During transformation of austenite at constant temperature below the pearlite range (800 to 400° F.). II(b). By transformation of retained austenite on tempering. II(c). During retarded cooling below 800° F.

III. From decomposition of martensite either during slow cooling through Ar''' or tempering.

Presumably troostite formed as in I would not be called troostite by the authors, but fine pearlite. II is "primary troostite", and III is "secondary troostite". ("Sorbite" has dropped out of sight.)

Primary troostite "consists of very fine ferrite-cementite lamellae, and differs from pearlite in that the lamellae are always straight and parallel to the (111) crystallographic planes in the austenite." It can be seen from this that "primary troostite", which to most American metallographers would mean excessively fine pearlite in nodular growths, is given a new meaning by the English authors, who would have it refer to the lately discovered acicular product of intermediate transformation known to us as "bainite".

The "secondary troostite" formed as in III as the first stage in the tempering of martensite is apparently troostite by analogy, for the authors say, "It appears, from analogy with other changes of a similar nature, that the cementite first forms minute films parallel to the crystallographic planes in the iron," possibly of molecular thickness, soon to ball up into invisible spheroids by surface tension.

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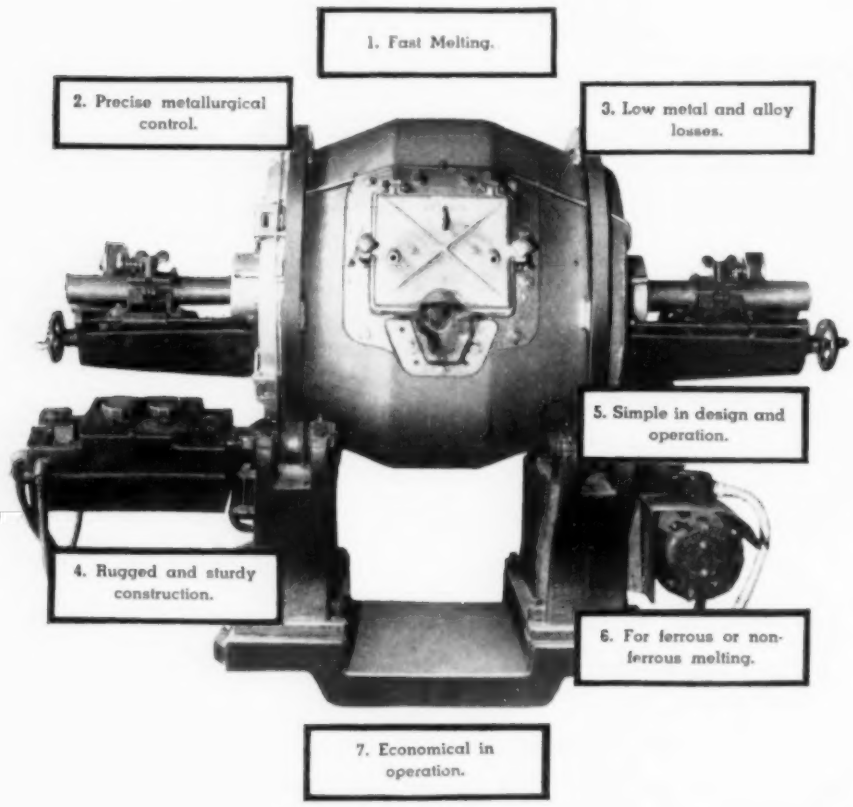
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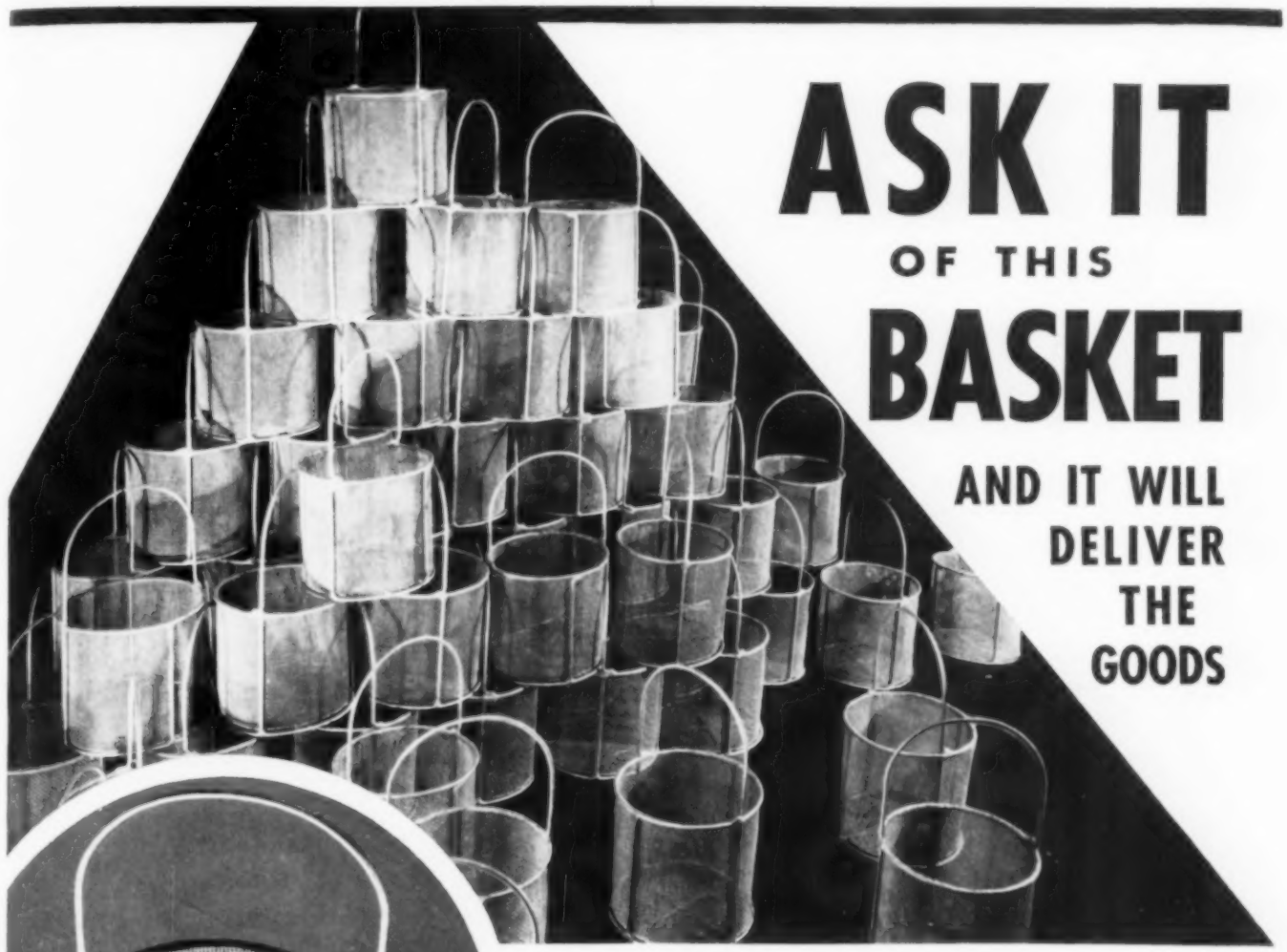
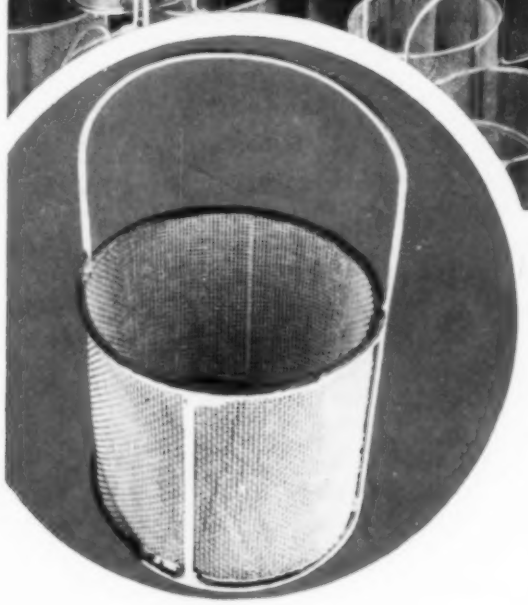


ASK IT OF THIS BASKET

AND IT WILL DELIVER THE GOODS



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FRICTION AND VIBRATION

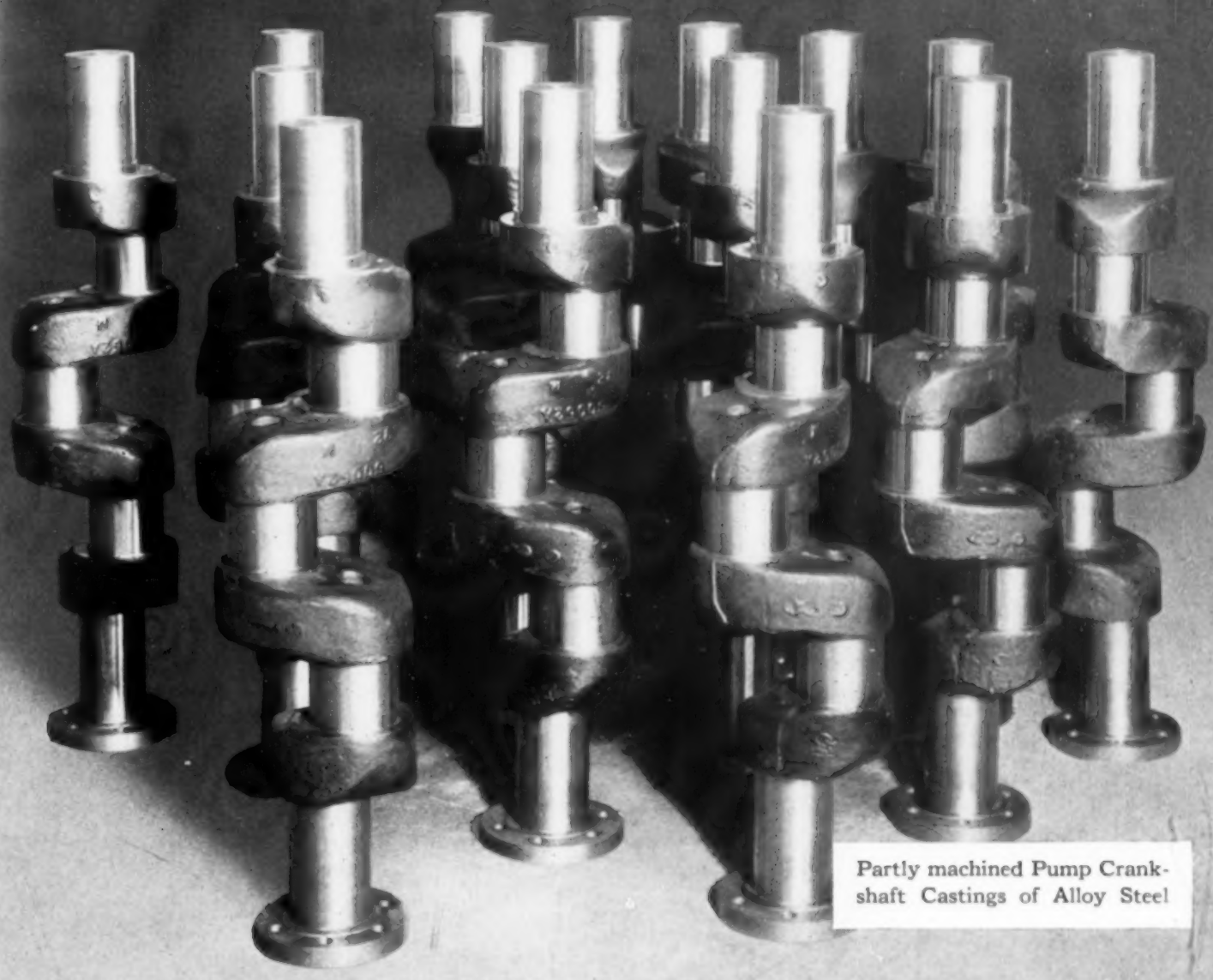
(Cont. from page 435) and the general behavior suggests that the surfaces are held apart by the small irregularities. Local pressures at the points of contact will be very high, and may cause the steel to flow plastically, forming junctions whose cross-section is sufficient to support the applied load. Similar junctions will occur when the surfaces are sliding one against the other.

Earlier experiments have shown that the surface temperature of sliding metals may easily reach the melting point, although the mass of the metal remains quite cool. At very low speeds the temperature rise is small, but at sufficiently high speeds softening and melting will occur at the points of contact. This is responsible for the observed change of Type I into Type III sliding, after the high melting point metal has picked up and welded on itself enough of the softer metal.

Conductance measurements indicate that in Type II the area of intimate contact is maximum just after the slip; local high pressures may weld the softer, lower melting metal to the other. During the stick the increasing pull will draw out these junctions thinner and thinner until they suddenly break when slip occurs and the process is repeated. The high melting metal is therefore left untouched with very small blobs of the softer adhering to it. In the sliding of a steel journal on a bearing surface of lower melting point, the local pressure cannot rise above the flow pressure of the bearing metal. The alloy will flow but the steel surface will not be affected. At sufficiently high speeds the frictional heating will cause the lower melting white metal to soften or melt; the higher melting steel will, however, remain undamaged.

Experiments with weighted surfaces and more rigid suspensions indicate that this intermittent clutching and breaking away of metal surfaces occurs in very short periods, less than 10^{-4} sec. (The relative movement at the slow speeds is only a distance of several atom-diameters.) Characteristic squeaks showed that the frequency of the stick-and-slip corresponded to that of the noise.

The importance of these conclusions in engineering practice is clear. The stick-slips at the surface may set up vibrations in the moving parts. Even if the moving parts are made very rigid the stick-slips and the resulting vibrations may not be eliminated. The frequency of the stick-slips will tend to increase until some other part of the system vibrates at the higher frequency. Lubrication will not necessarily produce smooth motion. As we have already seen, lubricated surfaces may often behave in essentially the same way as unlubricated ones.



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2 Metal distributed where it will do the most good; maximum strength with minimum weight.

3 Widest range of mechanical properties.

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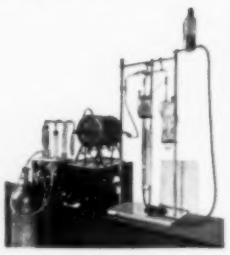
STEEL CASTINGS

MODERN ANALYSIS



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GAS ENGINE VALVES

(Continued from page 418) induced in them by heat treatment is lost. The austenitic steels — like 14 Cr, 14 Ni, 0.50 C, 0.75 Si, 2.0 W and 0.50 Mo — are only moderately hard at atmospheric temperature, say C-25, but retain a good measure of this hardness at elevated temperature. Similar steels with enough silicon or molybdenum to "age harden" at 1600° F., more or less, by the precipitation of an intermetallic compound, are especially interesting from the standpoint of hot hardness. Austenitic steels are not, however, very wear resistant, so their stems are frequently nitrided.

Valves of the mushroom or flat top type sometimes fail from heat shock, as when a bus engine at the top of a long hill is suddenly used as a brake on descending in low gear, and the red hot valves may then be cooled with unburned fuel. Such quenching stresses are much lower in valves whose heads are dished upward in a "tulip".

Owing to the fact that most aircraft engine valves are internally cooled (molten sodium carrying heat back from the head down into the stem and out through the generous sleeve), their temperature is usually much less than that acquired in a laboring engine on bus or truck. Likewise the conditions, cylinder to cylinder, are more uniform. Therefore the conditions of operation are more easily duplicated in laboratory testing of air engines.

Currently the austenitic steel whose analysis was quoted above is in practically universal use. Seating areas have layers of Stellite welded on in America; in England "Brightray" (80 Ni, 20 Cr) is preferred and sometimes the entire portion within the combustion chamber is so covered. Comparative tests made over here are inconclusive, since the relative order of superiority has varied, test to test. About 40% of American aircraft valves have stems nitrided to about 600 Vickers hardness. Valves completely fabricated from 80% nickel, 20% chromium are in experimental use in England and are understood to be completely satisfactory except in respect to stem wear and scuffing.

Material in the cylinder seat may have a pronounced influence on valve burning. Aluminum bronze seat inserts stand up as well as Stellite or Brightray, but in a given engine the valves may burn in a short time.

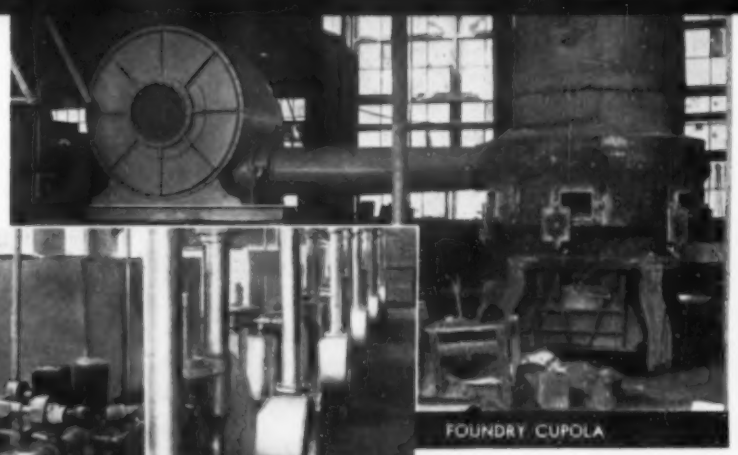
CORE AND MOLD OVENS, FOUNDRY EQUIPMENT CO.

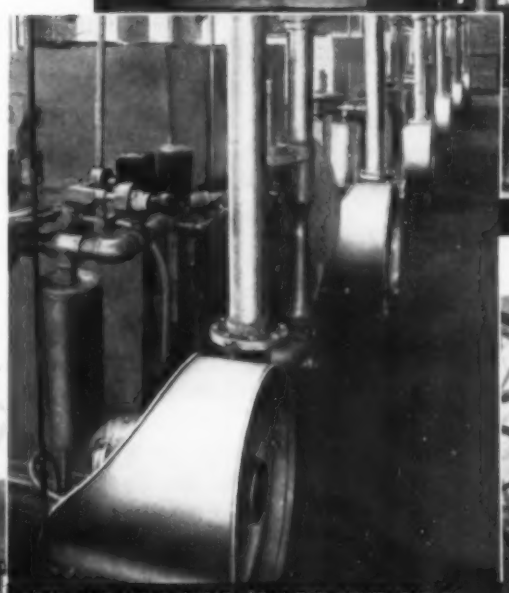
FOUNDRY SERVICE

Spencer Turbo-Compressors serve foundries in two widely differing ways. For cupolas, the large multi-stage Spencer Turbos with wide clearances and long life are distinguished by the fact that a constant air pressure is automatically maintained regardless of conditions inside the cupola. A calibrated ammeter permits accurate control of the volume of air from any point on the pouring floor.

Core ovens although operating at lower temperatures, nevertheless require a positive air supply coupled with reliability and efficiency.

Spencer Turbo-Compressors are consistent with the economic factors so important in cupola and oven operation. They have been repeatedly recommended by the leading manufacturers of foundry equipment for more than a quarter of a century.


FOUNDRY CUPOLA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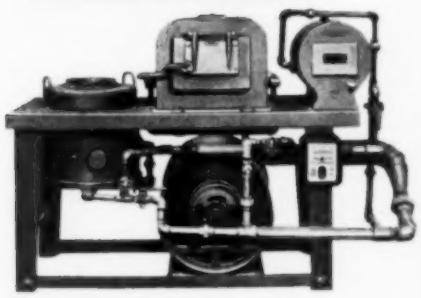

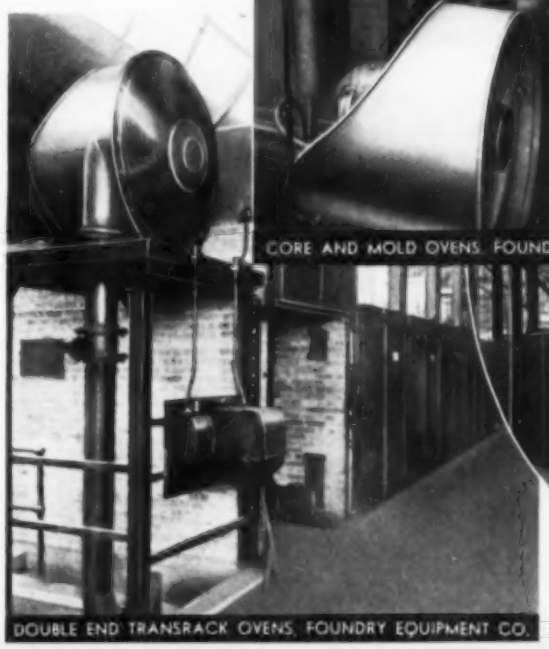
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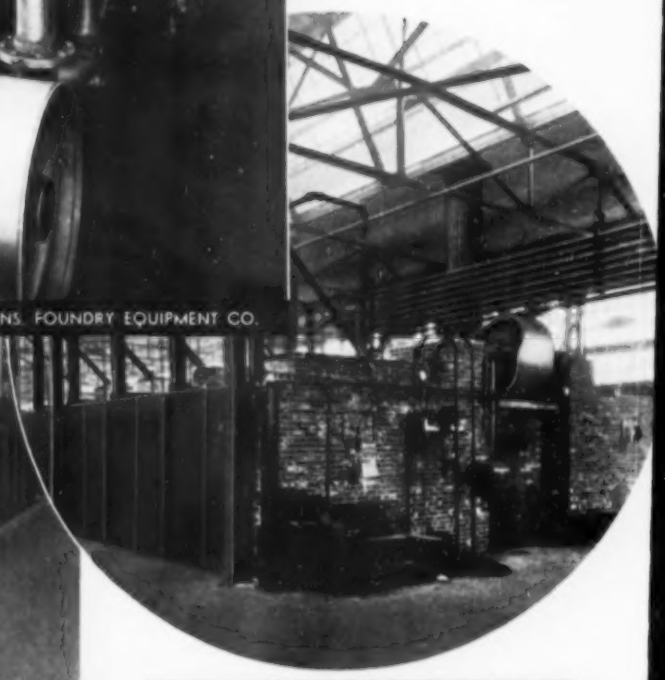
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CONTRIBUTORS

to this issue

Herbert Habart

Herbert Habart, metallurgist at the Ellwood Works of National Tube Co., got his B.S. in metallurgy from Case School of Applied Science in 1925, and his M.S. from University of Alabama in 1926. He has been with National Tube Co. ever since.

After a brief sojourn in the pharmaceutical department of Northwestern University, **Herbert R. Hanley** turned to the field of mining and metallurgy and went to Missouri School of Mines, graduating as a mining engineer in 1901. For 13 years he was superintendent of Bully Hill Copper Mining and Smelting Co. in California. Here he first became interested in zinc and spent four years in research on the electrolytic recovery of zinc from low grade ores. From 1916 to 1920 he supervised the electrolytic zinc and cadmium plant of United States Smelting, Refining and Mining Co., also finding time to get a metallurgical engineering degree in 1918 from Missouri School of Mines. After a three-year interval as a consulting engineer, he returned to his alma mater first as associate and then as professor of metallurgy. In the past 17 years at Rolla, Mr. Hanley has continued his research on zinc, the galvanizing process and other secondary metals, has taken out nine patents, and is the author of numerous papers.

Dartmouth College, University of Pittsburgh and the graduate school of Carnegie Institute of Technology were attended consecutively by **Robert S. Rose,** before he entered the metallurgical laboratories of the Vanadium-Alloys Steel Co. After four years grasping the complexities of mill and laboratory routine at both this and the Colonial Steel Works, he was in 1932 transferred to Springfield, Mass., in a sales-service capacity for the New England district. His title is now sales metallurgist — his ability to fill the first part of that job is adequately attested by his popularity among fellow ⊜ members (chairman Springfield Chapter 1934-35); his ability for the latter half by the article on toughness of toolsteels on page 407.

Out of Stanford University with a metallurgical engineering degree in 1932 (A.B. in engineering, 1929), **James W. Halley** found himself in the depths of the well-known depression. Consequently he might be congratulated on obtaining even such unmetallurgical and varied jobs as bank teller, news reel photographer and accountant during 1932 and 1933. Toward the end of 1933 he found an opening with Inland Steel Co. where he is now metallurgist. He is author or co-author of papers on steel castings, low alloy steels, rimmed steel and precipitation hardening, and has now joined forces with **Edwin Dudley Martin** to produce a paper on the health hazard in using lead-bearing steels (page 412). This paper is a supplement to one by Mr. Martin in the May 1939 issue, which gives his biography on page 488. Mr. Martin is assistant chief metallurgist in charge of development and research.

Herbert R. Hanley

Robert S. Rose

James W. Halley

Edwin Dudley Martin

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Measuring Metal Coatings

Measurements of local thicknesses of coatings on metals may be made in less than one minute by the Magne-Gage, an interesting instrument described in a 4-page folder by the American Instrument Co. Bulletin Cd-259.

Industrial Furnaces

A series of interesting bulletins showing Dempsey Industrial Furnaces in a wide range of requirements is now available through the Dempsey Industrial Furnace Corp. Bulletin Dd-260.

Chemicals

A complete line of Fluxes, Inhibitors, Zinc, Alkali Cleaners and Acids is described in a new catalog issued by Grasselli Chemicals Dept. of E. I. DuPont de Nemours & Co. Bulletin Dd-95.

Tocco Junior

A new induction hardening machine for hardening small parts is described in a new bulletin released by the Ohio Crankshaft Co. Bulletin Dd-145.

Steel Catalog

Helpful to all designers, engineers and fabricators interested in the use of high tensile, low alloy steel is a new 40-page catalog on Republic Double Strength Steel. Bulletin Dd-8.

Electric Furnaces

A four page bulletin on ⅛ lb. to 4 lb. high frequency melting furnaces and 3 kw. converter is now available through the Ajax Electrothermic Corp. Bulletin Dd-41.

Shear Knife

A handbook describing the development of the solid steel shear knife by Sam Heppenstall, founder of the Heppenstall Company. Compact, bound in imitation leather, this booklet contains valuable data in the form of a hardness conversion table and shear knife performance charts. Bulletin Db-122.

Aerocase

A modern method for case hardening and heat treating steel in a liquid bath is provided by the use of Aerocase compounds. Their principal features are described by American Cyanamid and Chemical Corp. in an interesting booklet. Bulletin Oy-148.

Gas-Fired Furnaces

Standard Rated Gas-Fired Furnaces produced by Surface Combustion Co. are included in a new catalog just released by this organization. Bulletin Fc-51.

Rayotubes

Specialized temperature measuring problems to which Rayotube detectors are now being applied are shown in an impressive booklet released by Leeds & Northrup Co. Bulletin Bd-46.

Galvanizing

An informative, historical, simple digest of galvanizing forms a guide to longer life for iron and steel products. This handsome, handy, 24-page book beautifully printed in color is distributed by American Hot Dip Galvanizers Association, Inc. Bulletin Ea-167.

Design

Designing greater sales appeal into products is explained in a colorful 8-page booklet for anyone who contemplates using, or is using, Stainless Steel, issued by the Carpenter Steel Co. Bulletin Nc-12.

High-Strength Steel Data

Complete mechanical property data on Ductiloy, a new low-alloy, high-strength steel, are given for strip, plate and bars in a folder of Great Lakes Steel Corp. Bulletin Ec-229.

Lectromelt Furnaces

The story behind lectromelt furnaces is well told in this 48-page booklet issued by the Pittsburgh Lectromelt Furnace Corporation. Tells of development of this type furnace and describes recent improvements. Bulletin Db-18.

Pyrasteel

All types of uses for Pyrasteel, the heat resisting alloy made by Chicago Steel Foundry Co., from astronomical plaques ruled 20,000 lines to the inch to huge kilns, are described in an illustrated pamphlet. Bulletin Cb-184.

USE THE COUPON ON PAGE 470 TO OBTAIN THIS HELPFUL LITERATURE

Heat Treating Furnaces

A 16-page booklet of Holcroft & Company shows and describes their line of controlled atmosphere heat treating furnaces. Bulletin Ec-203.

Alloy Castings

The "extra point" value of Michiana alloy castings is shown in a booklet released by the Michiana Products Corp. Typical installations are shown. Bulletin Nb-81.

Ingot Production

"The Ingot Phase of Steel Production" is the title of a book defining the principles of quality ingot production followed by many well-known steel manufacturers. Gathmann Engineering Co. Bulletin Ka-13.

Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in Bulletin D-17.

Heroult Furnace

Revised and expanded to include modern major innovations in the construction and operation of the Heroult electric furnace, the latest edition of the American Bridge Co.'s Heroult Electric Furnace Bulletin is available. Bulletin Bb-124.

Insulation

A 32-page catalog containing specific information on all of the sheet, block and pipe insulations developed by the Johns-Manville Company is now available through that company. Bulletin Fb-100.

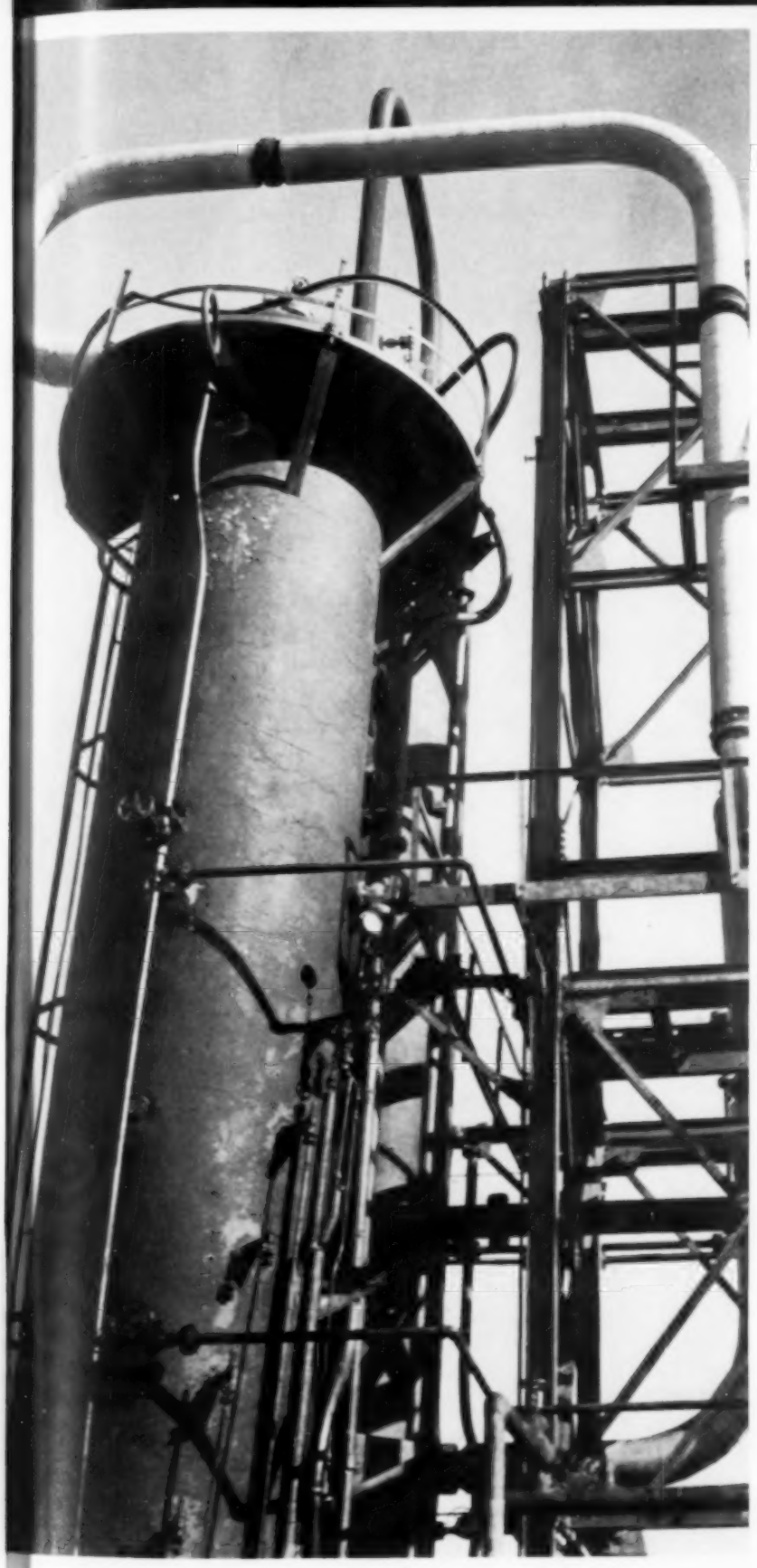
Hardened Gearing

Extremely valuable technical information on heat treated hardened gearing, including treatment, control and quenching, comparison of properties, etc., is included in a booklet by the Westinghouse Electric & Mfg. Co. Bulletin Hc-134.

Seamless Tubes

Prepared by the Timken Steel and Tube Division of Timken Roller Bearing Co. is a "Guide for Users of High Temperature Steels" which presents technical data relating to the various properties of Timken seamless tubes. Bulletin Bb-71.

When steels must work "RED"-



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A convenient ready reference wall chart showing mounted grinding wheels should be of great advantage in the cleaning room, pattern shop, tool and die room, and many other places. It gives at a glance, by means of detailed drawings, actual size, the exact radius of each wheel and its exact shape. Chicago Wheel & Mfg. Co. Bulletin Bd-230.

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A helpful, colorful booklet edited by experienced heat treaters is available through the Lindberg Engineering Co. Bulletin Bd-66.

Moisture Determination

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